MACKENZIE VALLEY PIPELINE INQUIRY

IN THE MATTER OF AN APPLICATION BY CANADIAN ARCTIC GAS PIPELINE LIMITED FOR A RIGHT-OF-WAY THAT MIGHT BE GRANTED ACROSS CROWN LANDS WITHIN THE YUKON TERRITORY AND THE NORTHWEST TERRITORIES FOR THE PURPOSE OF THE PROPOSED MACKENZIE VALLEY PIPELINE

and

IN THE MATTER OF THE SOCIAL, ENVIRONMENTAL AND ECONOMIC IMPACT REGIONALLY OF THE CONSTRUCTION, OPERATION AND SUBSEQUENT ABANDONMENT OF THE ABOVE PROPOSED PIPELINE

(Before the Hon. Mr. Justice T.R. Berger, Commissioner)

Yellowknife, N.W.T.

March 3, 1975.

PROCEEDINGS AT INQUIRY

VOLUME IX

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APPEARANCES:

Mr. Ian G. Scott, Mr. Stephen T. Goudge, Mr. Alick Ryder and Mr. Ian Roland	for Mackenzie Valley Pipeline Enquiry;
Mr. Pierre Genest, Q.C. Mr. Jack Marshall, Mr. Darryl Carter, and Mr. John Steeves	for Canadian Arctic Gas Pipeline Limited;
Mr. Reginald Gibbs and Mr. Alan Hollingworth	for Foothills Pipelines Ltd.;
Mr. Russell Anthony, Prof. Alastair Lucas & Dr. Andrew Thompson	for Canadian Arctic Resources Committee;
Mr. Glen W. Bell and Mr. Gerry Sutton	for Northwest Territories Indian Brotherhood and Metis Association of the Northwest Territories;
Mr. John U. Bayly	for Inuit Tapirisat of Canada and the Committee for Original Peoples' Entitlement;
Mr. Ron Veale and Mr. Allan Luke	for Yukon Native Brotherhood;
Mr. Carson H. Templeton	for Environment Protection Board;
Mr. Murray Sigler	for Northwest Territories Association of Municipalities and Northwest Territories Chamber of Commerce

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OPENINGS

Yellowknife, N.W.T.,
March 3, 1975.

(PROCEEDINGS RESUMED PURSUANT TO ADJOURNMENT)

THE CHAIRMAN: Ladies and gentlemen, this enquiry has been established to consider what the impact will be of the pipeline that Arctic Gas wants to build to bring natural gas from the Arctic to southern markets.

We are today beginning the formal hearings of the enquiry. In these formal hearings we will be examining the multitude of studies and reports that have been prepared by the government, by the industry, and by the participants. There will be the fullest opportunity for the ventilation of the evidence, the opinions, and the arguments of all concerned.

But I want to make it clear that the enquiry will not be limited to these formal hearings. We will be holding hearings in every community in the Mackenzie Valley likely to be affected by the pipeline. At the community hearings there will be an opportunity for the people who live in the valley to tell me what they think, and to say what they want to say.

To enable the people in the cities and towns, the settlements and villages in the Mackenzie Valley, to know what is being said here in Yellowknife at the formal hearings, summaries of the evidence given will be broadcast on a regular basis to all of the communities, in English and the native languages.

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The proposed pipeline is not to be considered in isolation. The Pipeline Guidelines laid down by the Government of Canada require an examination of the proposed pipeline in the context of the development of a Mackenzie Valley Transportation Corridor.

So we are embarked on a consideration of the future of a great river valley and its people. I want the people who make this valley their home to have a chance to tell me what they would say to the Government of Canada if they could tell them what was in their minds. Then it will be my task to report to the Minister of Indian Affairs and Northern Development regarding the social, economic and environmental impact of the project here in the north, and to recommend the terms and conditions that should be imposed with respect to any right-of-way that may be granted for the pipeline.

It will be for the Minister and his colleagues - for those who govern our country -- ultimately to determine whether there should be a pipeline, and the terms and conditions that should be imposed with respect to any right-of-way.

Mr. Scott?

MR. SCOTT: I would like at the beginning to review some of the steps that have been taken to prepare for this enquiry, and the plan that we contemplate will be followed as we proceed with the formal and community hearings. As you will know, sir, of course, late last year and in the spring there

were two full preliminary public hearings at which the participants and the public were invited to make recommendations to you, as to the nature of discovery before hearing, and as to the nature that the formal and community hearings themselves should take.

Following those full public hearings, your preliminary rulings were made, the last of which was made in the autumn of last year.

Since that time and in compliance with your rulings, each major participant has filed a list of reports and studies within his possession or power and inspection of those reports and studies by other participants and interested persons has been had or is at least well under way. The object of that exercise, of course, is to assure that before hearing and before evidence there will be full disclosure by everybody of all technical and other relevant material in the possession of the parties. In compliance with the duty imposed upon me, I have filed with the Commission a list of reports and studies in the possession of the Government of Canada which are also, as noted in the preamble to that list, available for inspection by all participants.

A Committee has been established respecting community hearings under the chairmanship of Professor Jackson of the Commission staff, and it is made up of all interested parties including the Northwest Territories Association of Municipalities, Arctic Gas, and representatives of the organizations of native peoples, and is presently at work planning the

format and timing of hearings -- community hearings -- to be held in all the communities and settlements of the valley and the delta.

The Government of Canada Assessment Group has in addition filed its report and has made to the applicant its requests for supplementary information.

Arctic Gas has in turn filed its response to that request. All of that material is now or will be available for inspection in the office of the Commission in the Resources Building at Yellowknife.

Mr. Commissioner, the overview directed by you in your first preliminary rulings will begin tomorrow. We will bring evidence before you that is designed to provide a backdrop against which the position of the applicant and the intervenors and the interested persons in the territories may be seen as the hearings progress.

The overview evidence is designed to include, in a general way, such matters as the history, culture, and economy of the northern peoples, the geography and theological history of the MacKenzie Valley, the delta and the Yukon, the climate, the geotechnical aspects of northern construction, terrain types, including permafrost and resources, renewable or non-renewable.

After the overview hearing is completed, that is in approximately one week's time, we will commence the formal hearings of the inquiry in which we will examine in four, perhaps more, but certainly four phases, the application of Arctic GAs. The division of those phases and their general ambit has been set out in your preliminary rulings.

Phase one will deal with the engineering and the construction of the proposed pipeline and at these hearings there will be evidence

dealing with such matters as the size of the pipeline, its location, the timing of construction, the composition and deployment of construction crews, the construction of compressor stations and matters of that kind.

Following upon phase one will come phase two in which we will consider the impact of a pipeline and the MacKenzie corridor development on the physical environment. This phase of the hearings will include the impact on the land, the air, and the water and will cover in detail such things as the effect of the pipeline on permafrost, river crossings, slope stability, gravel, and other bore hole locations and matters of that general description.

Phase three will deal with the impact of the pipeline on the living environment and in this phase you will be asked, sir, to give detailed consideration to the impact of the proposed pipeline on plant and animal life, including wildlife, mammals and fishes.

In phase four we will consider the impact of the pipeline on the human environment and here of course you will hear much evidence that will deal with the anticipated impact of the pipeline on the social and economic life of this community.

Today, the opening day, is reserved for opening statements by the major participants. Before coming to that I want to emphasize as firmly as I can that this is designed to be an open inquiry and there will be opportunity for

every person, whether represented by a lawyer or not to participate by way of asking questions or making statements and if you wish, any of you, assistance in doing that, please let Mr. Waddell of the Commission Staff know, or let me know and arrangements will be made for a convenient time when you can present your position as an individual or present your question to the panel of witnesses that may be giving evidence.

The purpose of the opening statements today derives from the fact that there are a number of participants who have indicated to the Commission that they propose to be a continuing presence in these inquiries,in this inquiry, and are prepared to take a firm position on all the major issues that it is anticipated will come before you.

As a result of that fact, it was thought to be orderly and desirable to permit them to make a short opening statement each in which it is anticipated they will detail their approach to the issues and the case that they intend to advance before you.

I wish to repeat an observation that was made in the preliminary hearings about the role of Commission Counsel. We have been assigned a specific role by you, sir, under your preliminary ruling. I emphasize that in addition to the obligations that are cast on us there, we intend to take throughout a positive and active posture in these hearings to assure that every view is tested and heard.

This is done in compliance with your clear injunction that this enquiry must be a full and a fair one.

So, sir, with some trepedation we are prepared to begin. It is, I think, for all of us a solemn and an important moment. The experience beginning today, as you have said, sir, is unique in Canadian history, and we begin with the hope that recommendations of the enquiry will in the end be uniquely useful for the people of this great valley and for the people of Canada. A great judge of this Territory once said that justice must be taken to every man's door, and that to a marked extent has been the watchword of our preparation as your counsel. The enquiry will be long; it will be detailed; it will be arduous. But we pledge that it will be open. The enquiry will hear not only from scientists and builders and government people, but it will be taken to the people by radio and television and in turn the enquiry will go to the people at hearings in each community.

Sir, it is our hope that by this effort the enquiry will be a model for the planning of great national developments in the future. I'm obliged, sir.

THE CHAIRMAN: Thank you, Mr. Scott. Mr. Genest?

MR. GENEST: Mr. Commissioner, I am grateful to Mr. Scott for having pronounced my name correctly because -- and to you, sir -- because in the last two years I've spent a considerable amount

of time in the north, and I have found the greatest difficulty in having my name pronounced correctly. I understand you, sir, suffer from somewhat the same difficulty with the hard "G".

As you know, I represent the Arctic Gas, and I thought it would be appropriate to commence my opening statement by introducing to you and to the participants and the public the counsel who will or may be appearing on behalf of Arctic Gas from time to time in these proceedings, and again give you the correct pronunciaton of their names.

I appear, together with Mr. Marshall, Jack Marshall from Calgarv; Mr. Darryl Carter of Yellowknife, and Mr. John Steeves of Vancouver. Mr. Commissioner, these may seem to some to constitute an excessively large gaggle (if that is the proper word) of lawyers, and I should explain why we have felt it necessary to be here in such numbers.

As you know, before it can proceed with the pipeline which is the subject matter of these hearings, Arctic Gas must go through at least three major hearings: the first to start is yours, sir, at the conclusion of which you will be filing your report to the Minister of Indian Affairs and Northern Development; secondly, there will be very extensive hearings before the National Energy Board of Canada for a certificate of public convenience and necessity; thirdly, extensive hearings will be held by the Federal Power Commission in the United States in respect of

those portions of the total project which relate to the United States. It now appears that all three of these hearings will be at one time or another running concurrently and in many cases covering the same ground. It may become necessary for us from time to time to detach certain of the legal counsel to attend to those other hearings. Indeed, at the present time Mr. Goldie who appeared before you at the Preliminary Hearings as the chief counsel for Arctic Gas, has disappeared into the National Energy Board and is engaged fulltime before the Energy Board in its hearings into the supply and demand of natural gas in Canada. So in order to provide continuity and to assure that your hearings will have the assistance of well-briefed counsel on the part of Arctic Gas, whose every facet is being examined in these hearings, we have felt it a wise precaution to brief this number of counsel.

Having dealt with counsel, sir, I should now like to say a few words which may be repetitive to some, but which I think bear repeating to describe Arctic Gas and tell you briefly what it is.

Canadian Arctic Gas Pipeline Limited and its sister company, Canadian Arctic Gas Study Limited, are companies incorporated under and subject to Canadian laws. Its present sponsors include a group of enterprises which have amongst them a number of companies engaged in the business of exploring for and producing oil and natural gas, a number of companies engaged in the business of transmitting natural gas, and a number of companies engaged in the business of

distributing and selling natural gas to the homes and industry of Canada and United States.

Canadian interests are substantially represented in the group of sponsors and the management of the companies is almost entirely Canadian. This pipeline will, if constructed, be subject to National Energy Board regulations, including regulation of its rate of return. It will be what is called a contract carrier, that is a company involved in the transmission or transportation of gas only., ready to carry gas for anyone in accordance with a tariff which must be approved by the National Energy Board of Canada.

If this project receives the necessary approval, sir, and gets underway, the owners of the equity, that is those who will then control the company, are not necessarily going to be its present sponsors. Indeed it is the intention of the management of Arctic Gas and of its sponsors to raise the majority of the equity financing for this project in Canada and it is expected that the majority of this equity capital, the majority of the controlling votes in the share capital of this company will be owned in Canada by Canadians.

The Arctic Gas companies were brought into existence by reason of the concern of its sponsors over a possible shortage of natural gas facing Canada and the United States. That possibility has now become a fact. Extensive studies were carried out into the feasibility of making available to the people of Canada the gas supplies which were thought to exist in the Northwest Territories and to the people of the United States, the gas found to exist on the north slope of Alaska at Prudhoe Bay.

An amount in excess of $75,000,000 has now been spent by the sponsor groups in order to carry out what I can call without hesitation the most extensive and thorough preliminary engineering, environmental and sociological study ever given to any project anywhere. Further substantial expenditures are budgeted and I point out that all of these expenditures will be made before there is any assurance at all that the project will receive

the necessary approvals to get it started. The studies I have mentioned, sir, range from extensive engineering feasibility studies to studies of the socio-economic impact of the pipeline on the North and its individual communities, to studies on the habitat and nature of numerous species of the vegetation and wild life of the North and the impact of the possible construction of a pipeline upon them. They have been carried out by the most highly qualified people that were available to us, almost all of whom are Canadians. The full nature and extent of these studies and the high qualifications of the persons who carried them out will, I believe, become evident as these hearings progress.

Having briefly reviewed the identity of Arctic Gas, sir, let me now deal briefly with the project that it proposes to undertake. As outlined in our application, the project involves the construction and operation of a large diameter natural gas pipeline some 2,435 miles long and if you will turn to the map which I cannot see very well from over there, a little better over here, the route of the line is shown.

One leg which you would call a supply line, or a supply lateral, would commence at the Yukon-Alaska border connecting there with a pipeline to be constructed from the Alaskan gas fields at Prudhoe Bay; the other leg, or supply line would commence from the Taglu Field on the North Shore of Richards Island in the Northwest Territories of Canada; Another supply line will join this one from

the Parsons Lake area in the Northwest Territories. Now, these two main legs will join into a trunk or main line at Travaillant Lake -- I do not know if that is the way that it is pronounced here, but that is the way that it is pronounced in my language -- just south of the MacKenzie Delta. This main line will then proceed south down the Mackenzie Valley and then into Alberta where it will split into a number of lines designed to carry Canadian gas to Canadian users and American gas to American users.

What I have just described sir, is what we call in our application the "Prime Route". We have also described in our application what -- and that is not shown on the map on the wall -- what we call the interior route, which is an alternative way of bringing the Alaska gas supply leg into the main trunk pipeline. This is a route which will proceed through the Brooks Mountain Range of Alaska, then move east across the Alaska - Yukon border, through the Richardson Mountains of the Northwest Territories to join the Taglu supply line at the same junction point as would the Prime Route, that is near Travaillant Lake. This is a route which when the application was filed, we found less preferable than the Prime Route but which we are prepared to utilize should decisions either in Canada or the United States make the Prime Route not available.

I should also mention, sir,

that some weeks ago I advised the Commission and the Participants that Arctic Gas had then under study a further alternative route for bringing Alaska gas to the main trunk line, a route called the "Cross Delta Route" which instead of coming down on the west side of the Mackenzie Delta would go directly across Shallow Bay at the top of the Delta and join the main trunk line just south of Taglu. We will shortly be filing, sir, with the Minister and with your inquiry detailed information with respect to this alternative route.

I should like here, having described the project very briefly, to correct what appears to be a general misconception as to the escalation of costs on the project. The figure of $10 billion is being mentioned quite often as the cost of the Arctic Gas project, and that is not so. The original cost estimated as set out in our application was $5.7 billion. That is the cost of the project from the Alaska border to the Canadian-United States border. Our estimates of the effect of future inflation, that is the inflation that will take place -- the depreciation that will take place in the value of money over the life of the construction of this project, has brought our estimates of the total capital cost in escalated dollars to $7 billion, and not $10 billion.

This, then, sir, is in the briefest outline, is the nature of the project. It is a project which we submit is clearly in the national interest of Canada and which we also submit will bring substantial benefits to the people of the north, with whose well-being your enquiry is largely concerned. The reason we seek to build this undertaking is that it is the most economically feasible way to bring badly needed Canadian gas to Canadians. This statement is based on a few simple propositions:

1. Canada is faced with an imminent and serious shortage of energy, in particular natural gas, which will have extremely serious consequences for the people of Canada if action is not taken promptly to secure and transport to market new

sources of supply.

2. The United States is faced with a similar shortage.

3. There are extensive gas reserves situated in Canada's Mackenzie Delta which are urgently needed to alleviate the Canadian shortage.

4. Even more extensive gas reserves have been located in the Prudhoe Bay area of Alaska, which are also urgently needed by the United States to alleviate their own shortages.

5. Because of the existing level of proven reserves in the Mackenzie Delta, it is not economically feasible to construct a pipeline for the exclusive purpose of piping Delta frontier gas to Canadian markets.

6. The transportation of Prudhoe Bay gas to American markets by means other than a pipeline crossing the territory of Canada would be far more expensive.

7. The construction of a trunk pipeline which will carry to Canadians our own Delta gas and will carry to the United States its own Prudhoe Bay gas, is the only economically feasible solution for Canada at this time.

8. Lastly, while the discovery of a great deal more gas in the Delta would make possible a line for Canadian gas only, at some unknown time in the future, a joint line carrying both American and Canadian gas will always remain the most economic alternative.

In short, sir, what we believe this project offers to Canada is the presently most

economically feasible contribution to Canada's defence against the world energy crisis -- the best chance to reduce substantially Canada's exposure to the vast economic and financial problems which, if they are not solved or alleviated, are bound to seriously affect the well-being of every Canadian man, woman and child.

Mr. Commissioner, these are all propositions the validity of which will be examined in detail by the National Energy Board. The concern of your enquiry relates almost entirely to the consequences to the environment and people of the north, of the building and operation of the project, and it is to that subject that I now wish to turn.

Mr. Commissioner, the position taken by Arctic Gas in its application and which we hope to demonstrate to you and to the people of the north in these hearings is that the construction and operation of this pipeline, subject to proper safeguards and to management responsive to the needs of the north, will be of positive economic and social benefit to the people of the north.

Notwithstanding our position, that the effect of this pipeline in the north will be positive, let me state at once that we do not pretend and we do not allege that there will be no damage or impact by this pipeline. What we do say is that any environmental damage which will be caused will not be lasting, that it can be alleviated to a point where it will not significantly affect the northern environment. Again, we do not say that there will be no

impact on the lives of the people in the north. Some of these effects will be positive and some will be adverse. What we do say and what we hope to demonstrate during the course of these hearings is that the positive benefits of this project on the economy and life-style of the peoples of the north will far outweigh any negative effect.

Mr. Commissioner, the hard fact is that without some sort of economic development, this land -- this northern land, enormous, beautiful and awe-inspiring as it is -- is not now supporting the population of the Northwest Territories. The hard fact is that many northerners whose forebearers lived off the land do not want to go back to the traditional means of making a livehihood. The hard fact is that at present there is insufficient economic activity in the north to give the opportunity for all those who seek wage employme to fulfil themselves in these Territories. Indeed, sir, our evidence will show that a good deal of economic activity which is now taking place in the Territories is there by reason of the anticipation of the construction of this pipeline and that if the project were not to go forward, the pace of economic activity, the opportunities for job employment in the north would reduce to an extent that would work great hardship for a large proportion of the people now residing here.

Our case is, sir, that the north as a whole needs a sound and stable economic base which will provide wage employment for those who

wish to seek it. Our submission is that the pipeline will provide that economic base without interfering with or restricting the freedom of choice of those northerners who wish to earn their livelihood from the land.

In your preliminary rulings, sir, you declared that the contention of the native organizations that no pipeline development should proceed until the land claims of the native people have been settled was one which they were entitled to urge upon this enquiry; you stated that the native organizations should indicate to this enquiry the nature and extent of their claims so that, and I quote from the words of your ruling:

> "The enquiry will then be in a position to indicate to the Minister what measures ought to be taken to ensure that the native peoples in their negotiations with the government do not find themselves at any disadvantage owing to the building of the pipeline, and looking to the consummation of negotiations, what measures ought to be taken to ensure that whatever the extent of the native interests that may ultimately be recognized by any settlement, it will not be diminished by the construction of the pipeline in the meantime."

Sir, your ruling then properly went on to point out that the negotiation of a settlement of native claims in the north was a matter for the government of Canada and the native people and that nothing said at this inquiry can bind either side. Indeed, this inquiry is not the place where these claims can or will be settled but you did invite the native organizations to lay before the Inquiry a statement as to the nature and extent of their land claims.

Mr. Commissioner, Arctic Gas recognises the necessity for a fair and just settlement of the land claims of the native. Our position is that the pipeline can indeed be built without prejudice to the settlement of the native land claims and following the presentation to this Inquiry of the precise nature of these claims, we propose to make submissions directed to that issue..

Basically, sir, it is a function of your hearings to test and examine the validity of the submissions I have just been making. The Order-in-Council , dated March 21, 1974, constituting this inquiry provides that you are, and I quote, "to inquire into and report upon the terms and conditions that should be imposed with respect of any right of way that might be granted across Crown Lands for the purposes of the proposed Mackenzie Valley pipeline having regard to A) the social environmental and economic impact regionally of the construction operation and subsequent abandonment of the proposed

pipeline in the Yukon and the Northwest Territories and B) any proposals to meet the specific environmental and social concerns se t out in the expanded guidelines for the Northern territories."

The Order-in-Council has left you, sir, with broad discretion as to the methods you should follow in holding the inquiry authorized thereby. The preliminary rulings which you have made have dictated the course, scope and extent of these hearings and have insured that they will be a landmark in public inquiries of this sort. Every precaution has been taken to enable you in your own words, and I quote: ".. to conduct a fair and thorough inquiry , to give all those persons and organizations with an interest in the proposal made by Arctic Gas a fair opportunity to be heard."

With the co-operation of the Government, substantial funds have been granted by you to many of those who are here as Participants, representing special interest groups and special points of view to enable them to make a meaningful contribution to these hearings and to brief able and experienced counsel to assist them.

Mr. COmmissioner, we have tried in making our plans for this pipeline and in drafting our application to anticipate and foresee to the best of our ability the various problems which might occur as a result of the construction and operation of this project. Notwithstanding the expertise of the many people who have participated with us in

preparation of these plans, we do not claim to be the possessors of all wisdom. We believe that each of the participants here can make a valuable contribution in bringing forward the special points of view, the special concerns of the people and groups that they represent. Some of these we may have overlooked or given insufficient importance to and as a result the representations of these groups may cause you to recommend beneficial changes by the imposition of beneficial terms and conditions.

We do not look, sir, upon the participants here as opponents. We rather look upon all of us engaged in this inquiry as a group dedicated to the search for the best method of protecting the ligitimate claims and interests of the people of the north and the people of Canada.

Our objective, Sir, is not only to try and persuade you as to which terms and conditions you ought to report to the Minister should be imposed in respect of our right of way but it is also by full and frank disclosure to communicate to the citizens of the north of Canada our sincere desire that this project, which we say is essential to the well being of Canada as a whole, brings to the citizens of the North their proper share of the benefit. We hope to be here in the North long after this inquiry is over. We wish to live in the north as friends and neighbours of all of the people of the North and to enjoy their good will and trust and we hope that these hearings will help to achieve that

that purpose.

We also confidently look to you, Sir, for leadership in ensuring that these hearings which will deal with complex matters and conflicting points of view, do in fact fulfil their purpose. We look to you to keep all of us lawyers, who are used to the adversary system and I am the first to be guilty of it, there are sometimes excessively fond of the sound of our own voices, who look to you to keep us on the track so that when the hearings are completed the judgment as to how useful, how efficacious they have been, will not be that they have been so cumbersome and so lengthy that nobody should ever have a hearing like that again, but rather, as stated by Mr. Scott, in his remarks, that they will provide a model for hearings of this kind in the projects of this magnitude in the future. And I pledge, Sir, that Arctic Gas and myself and my co-counsel will do everything in our power to assist you in your formidable task.

Thank you very much.

THE CHAIRMAN: Thank you, Mr. Genest. Mr. Gibbs.

MR. GIBBS: Mr. Commissioner, My name is Reg Gibbs. I am counsel for Foothills Pipeline Committee. I have with me Mr. Alan Hollingworth who will also be appearing at these proceedings. It is probably more in keeping with the modest ambitions of Foothill Pipeline Limited that we have only two counsel compared to Arctic Gas' five, but of course, we do not

have to be concerned with hearings in jurisdictions other than in Canada.

Mr. Commissioner, Foothills Pipelines Limited welcomes the opportunity to make an opening statement to this inquiry. By way of preface perhaps I should make it plain for the benefit of all persons interested in the proceedings that Foothills is not an applicant but is what you have classified, Sir, as a participant. But to remove any lingering doubt there may be, or any hope that there may be in the collective executive breasts of the Toronto officers of Canadian Arctic Gas, I am pleased to report, Sir, that Foothills expects to file its first material with the appropriate authorities by the end of March, and to continue filings until that material is completed by early in May.

That material, Mr. Commissioner, will demonstrate beyond doubt that Canadian needs for natural gas can be satisfied through the Maple Leaf project at no greater expense in unit costs and at much lesser expense by any other yardstick in comparison with the Candian Arctic Gas proposal. It is, Sir of those underlying tangible and intangible expenses inherent in the Canadian Arctic Gas project that I propose to address you and I am grateful to my friend Mr. Genest for raising many of these points. I am sure that he will forgive me if I give them slightly different emphasis.

So Mr. Commissioner, the underlying fabric in many ways, I'm sure unintentionally, concealed by rhetoric and detail to this application constitutes what in my submission is a threat and danger, a threat and danger to the whole of the Canadian people and the Canadian nation.

It is eminently suitable, sir, that the first opportunity to examine the project as a whole and to deduce the intention behind it and the consequences which will flow from it if it is approved, should be here in the north. It is trite to say, sir, that without a grant of user of Crown lands Canadian Arctic Gas will have no foundation, and without a foundation, sir, the project will find its proper place which, in my submission, is in the history books. It is appropriate, sir, before we commence the weeks and the months of the details of the proposal, to look at the broad outlines and recognize the project for what it is and what it is not. The recognition should then stay with us and be the background against which the details are superimposed for examination.

Mr. Commissioner, let us first recognize that the Canadian Arctic Gas project is not designed to meet Canadian needs. I don't have, sir, the Toronto sophistocation, so I form my conclusions by the usual process of simple logic. I took the Canadian Arctic Gas affiliated company's -- and their affiliated companies statement written and verbal, and did some arithmetic, sir. I found a 48-inch pipeline with an economic operating capacity of 4 1/2

billion cubic feet running from Prudhoe Bay across Yukon and the Northwest Territories to Travaillant Lake. I found a 48-inch pipeline with a similar economic operating capacity of 4 1/2 billion cubic feet coming down from the Delta and joining the western link at Travaillant Lake.

I added those two together, sir, and found that their total capacity is 9 billion cubic feet per day.

I then went to the affiliate's filings, Mr. Commissioner, and looked to see what was happening south of the 49th Parallel, for the Canadian Arctic Gas portion is just a link in this gigantic system. South of the 49th Parallel, sir, I found running from Kingsgate south -- Kingsgate, British Columbia -- two new 42-inch pipelines, each with an economic operating capacity of 2 1/4 billion cubic feet per day. When I added those two together I got 4 1/2.

I then went to the east and found running south from Mouncie, Saskatchewan, a new 48-inch pipeline with a capacity of 4 1/2 billion cubic feet per day, and if you add all of those volumes crossing the 49th Parallel, they come to 9 billion cubic feet per day, the same amount that is going to come together if the pipelines operate at capacity, at Travaillant Lake.

It seemed to me a reasonable conclusion that everything that came in the north must go out the south. I asked the Canadian Arctic Gas representative about this on the witness stand in another place and he told me, sir, that that was

coincidence. Now I ask, should we accept that? Or might we be a little skeptical and conclude that in line with pipeline economics, which say that lines must be operated at capacity in order to keep unit costs down, that in a very short time everything which comes in at the north indeed must go out the south, in other words that this system, as drawn on the map, clearly and demonstrably intends that Delta gas will go into export.

There is another part of the design and capacity scheme, sir, that begs for recognition, and is perhaps somewhat more pertinent to your enquiry and that is this. If we go back again to the north and get these two 48-inch tunnels coming together at Travaillant Lake with a 9 billion cubic feet capacity, we find that they run into a single 48-inch pipeline with a 4 1/2 billion cubic feet capacity, and I remind you, sir, that south of the 49th parallel we have 9 billion cubic feet capacity. I have several times tried to find the logic of feeding two, or squeezing two 48-inches into one. I haven't yet been rewarded with an explanation. I sincerely hope, sir, at a very early stage of this enquiry a rational explanation is demanded. But sir, without even waiting for it, if one applies again my country logic, without it being obscured by engineering data, that logic tells me that every effort will and must be made to achieve economies of operation in the northern extremities and the southern extremities; and to achieve those economies of operation and operate at maximum economic capacity I forecast, sir, that there will be irresistible and irrefutable arguments

that the main 48-inch line comes from Travaillant Lake down to Carolina, Alberta, must be doubled in size. Implicit therefore in a system design is that a grant of user of Crown lands south of Travaillant Lake is not for one 48-inch pipeline but for two.

Let us then, sir, turn to the question of Canadian control, which my friend raised. The same Canadian Arctic gas witness with whom I spoke about 48-inch pipelines told me that of the 20 corporate sponsors which he has, only five can be genuinely called Canadian. There's not much Canadian control there, sir. With respect to Canadian ownership, we are told by statements eminating from Toronto that the intention is that there will be an opportunity for Canadians to subscribe at one time it was for half the equity and now I gather this morning it's for a greater amount. Well, sir, that's cold comfort.

I grew up in an area secure in the knowledge which I am sure is shared by northerners that the road to Toronto is paved with good intentions. Sir, that thesis of Canadian ownership cannot ever be more than a good intention. My friend has repeated to you this morning that in escalated costs the capital expenditure for the Canadian portion of this system will be something in the order of $7 billion.

Traditionally utilities are financed on the basis of 25% equity and 75% debt. By my calculations, sir, 25% of $7 billion is $1.8 billion, and only half of that even is $900 million. Now, sir, I'm sure that even the most sanguine of the

Canadian Arctic Gas promoters will agree with me that it is absolutely and unequivocably impossible for Canadian public subscription to reach the range of $900 million for this type of new and untried project.

To put it in perspective, sir, according to Bank of Canada statistic figures, that amount of $900 million is equal to the total equity issues of common stock in Canada for the years, 1972 and 1973 combined. With the greatest respect, sir, I submit that it is frivolous to say that 50% of the equity will be raised by Canadian subscription. Even if that were possible, sir, of course that would not represent control. Those of us who have been exposed to business activities in Canada and elsewhere are familiar with many corporations where 10% of the equity represents control.

Mr. Commissioner, let us also be realistic and recognize that regardless of ownership, or equity ownership, there cannot be physical Canadian control. The ultimate test of control, sir, is the ability to stop the flow, and I predict that we will not have that ability in Canada. This flow of new gas, sir, through these new pipeline systems will go to markets in United States which will come to rely upon that gas for supply. There will be schools and hospitals and residences and businesses who depend on what is carried through that new highly visible 4-foot tunnel from the Arctic, and that, sir, will rapidly assume the character of a very visible and indispensable lifeline. It's very visible on the very map that has

been placed on the wall, sir. I am sure that we are all sufficiently familiar with world politics to know that nothing will be permitted to interfere with the sustenance which that gas flow will represent.

Sir, Canadians do not need to expose themselves to that type of trouble or possible confrontation.

Now, sir, I invite you to award another recognition and that is that this use of Crown lands which is requested will, if granted, represent the underpinnings for a project which runs directly counter to Canadian historical

With one significant exception, sir, factors through out our history as a nation, there has been insistance that main Canadian transportation and communication systems follow all-Canadian routes, with only convenience connections across the United States border. The examples are present for all to see. The Canadian Pacific Railway. The Trans-Canada Highway. The Telephone and Telegraph Systems. Trans-Canada Pipeline. The Air Canada, and so on.

The exception, the consequences are spoken of in sorrow by others more eloquent than I am, is the Columbia River Treaty, and this insistance, Mr. Commissioner, on all-Canadian routes has, in my submission, been one of the greatest single factors which has preserved the integrity and sovereignty of Canada. It seems incredible to me that there would now be proposed at this stage in our history that we should abandon all we have learned and favor construction

of what has been described as the equivalent of a Panama Canal across Western and Northern Canada.

Furthermore, sir, that we should be expected willingly and gratefully to use Canadian land, Canadian treasures, and Canadian talent to do this, to the end that there can be sucked away to foreign uses a precious Canadian resource which will be needed by Canadians. To use a colloquialism, sir, who needs this project? Certainly Canada does not need such a gigantic system designed primarily for foreign purposes. If there were no other way for a market to get that much-needed gas from its own territory, there might be some persuasions which could be advanced. But we know, sir, that there is another means of transportation for the foreign gas without taking it, mingled with Canadian gas along a Canadian right-of-way.

I do not, sir, mean to suggest that Canadian markets will not need Beaufort Basin gas. On the contrary, Foothills staff and consultants working with the most recent available data forecast a need at the latest by 1979 and probably a year or two before, but why not, sir, supply this need through a simpler, more manageable, more modest, more Canadian approach? Why not build at a quarter of the cost a smaller line just far enough to connect with existing systems in Northern Alberta and British Columbia? Why not let those systems carry the gas the rest of the way to market along their rights-of-way, expanding as market conditions require, and using spare capacity as deliverability from provincial sources decline? Why

not by this means preserve, not merely in intent, but in actuality Canadian ownership and control throughout? Why not avoid those wholly new huge border-crossing pipelines with the threat they propose? Why not restrict the use of Crown lands for wholly Canadian use? The carriage of Canadian gas to Canadian markets through Canadian systems. By a pure coincidence, sir, that is exactly what Foothills proposes with its Maple Leaf project.

Those, Mr. Commissioner, in my submission, are questions to which Canadian Arctic Gas must give, at a very early stage, frank and forthright answers.

Throughout, Mr. Commissioner, I have been speaking in my capacity as counsel for Foothills Pipelines Limited, but were I addressing you as an individual I would have made exactly the same points; for Mr. Chairman, I am as concerned and apprehensive as a Canadian, as the northerners I have heard of on the radio in recent days. With all the force that I can command I urge, sir, and plead that we avoid the dedication of a north-south corridor, no matter how narrow, to foreign use and control in perpetuity. Whatever project is approved, sir, let it not be one which will physically divide our nation. Thank you.

THE CHAIRMAN: Thank you, Mr. Gibbs. Mr. Anthony?

MR. ANTHONY: Mr. Commissioner, before beginning the opening address on behalf of the

Canadian Arctic Resources Committee I would like to introduce myself and the other counsel for the Canadian Arctic Resources Committee to you. I am Russell Anthony, a member of the Bars of British Columbia and the Northwest Territories, and have the pleasure of appearing before you as counsel for the Canadian Arctic Resources Committee. With me from time to time will be -- as associated counsel -- will be Professor Alastair Lucas of the Law School of the University of British Columbia and the Bars of Alberta; with me this morning at the counsel table is the chairman of the Canadian Arctic Resources Committee, Dr. Andrew Thompson.

Mr. Commissioner, this enquiry has heard at Preliminary Hearings and will hear today northern people speak about their land and heritage. We will also hear representatives of southern Canada share their perceptions of the north and how it relates to the future of Canada as a whole. We do not intend to add to their eloquence; instead, we wish to direct our remarks to questions of public access, public participation and public accountability.

Prime Minister Trudeau spoke a few weeks ago in Montreal about the growing suspicion with which Canadians view their political institutions. He lamented the lack of trust so prevalent throughout the country and seemed to imply that the fault lay south of the 49th Parallel owing to Watergate and related events.

The Prime Minister surely is right to identify this growing cynicism. A review of

resource development decisions demonstrates, however, that his own government must bear a great deal of responsibility for the creation of this mistrust.

In the years 1968 to 1972, major decisions were made for Northern Canada. Everyone is familiar with the Prudhoe Bay discovery, the "Manhattan" voyage, questions of Arctic Sovereignty, off-shore drilling and the Mackenzie Highway. What is documented about those events is not reassuring. What little policy there existed for energy and northern development was based on hopelessly inadequate information. Furthermore, conscious efforts were made to exclude the public. Not even Parliament was informed about many of the discussions that took place between industry and government.

Fundamental principles such as government impartiality and the independence of regulatory agencies were distorted by officials in the development of petroleum resources in Northern Canada. At the same time those federal bureaucracies consistently pressed for delegation of important areas of authority to themselves and then closed ranks to obstruct public accountability.

One of the most important regulatory bodies in Canada is the National Energy Board. The N.E.B. is referred to as an independent arms-length tribunal. However, the N.E.B. was and continues to be involved in day to day consensus-building within the Federal Government. It has also been involved from the beginning with the planning of

northern pipelines. Does it not breed distrust for Canadians to learn that the most important regulatory body in this country has been so directly involved in schemes for northern development?

It was events such as these that led to the formation of the Canadian Arctic Resources Committee in June, 1971. From its earliest days C.A.R.C. has stressed the theme of participation --

"to open a window on the north,"

was the way our first chairman described it. C.A.R.C. does not believe that policies should be made behind closed doors and then "sold" to the public, nor that crucial choices affecting the future of the north should be made exclusively within the confines of a bureaucracy.

To unravel this process, and to present and explain alternative policies to the public, has been viewed by C.A.R.C. as its most important task. We have consistently argued that new review procedures are necessary if Canada is to avoid the reckless ad hocery that has characterized so much development on our national estate.

For many, the establishment of this enquiry gives promise that the era of mistrust will pass. It is with optimism that we have prepared our submissions to you. But what has been the response of the Federal Government of this enquiry?

While the Government pipeline application assessment group is to be commended for its work, the Government itself has been evasive and un-co-operative. Apart from the applicant, the Government is the largest source of crucial information about the proposed pipeline. As with the other participants, it was requested by you, Mr. Commissioner, to provide a complete list of documents relevant to this inquiry by November 30, 1974. The government list was not submitted until the end of January, 1975 and then only after the Canadian Arctic Resources Committee threatened to bring proceedings to compel production of the documents.

Immediately upon receipt of the Government list, C.A.R.C. wrote to Commission Counsel requesting production of these documents. To date the Government has not complied and in our opinion therefore, that a proper review of Government studies cannot yet be made.

Furthermore, the Government's list is seriously deficient. First, the list of documents prepared by the Government departments that responded was incomplete. C.A.R.C. even with its limited resources has identified many significant reports in the position or power of the Government and its departments that have not been revealed.

Secondly, the Government list of documents excludes the reports of such obviously important agancies as the Northern Transportation Company Limited and the Northern Canada Power Commission.

The Canadian Arctic Resources Committee has further written to Commission Counsel requesting that the reports that these agencies be provided to this inquiry. To date the Government has not replied and we are therefore launching into this inquiry without the opportunity of reviewing these studies.

The most recent actions of the Government increase our apprehensions. Newspaper reports of the last few days reveal that the Department of the Environment was instructed and apparently by Cabinet order, not to intervene in these hearings. As unfortunate as that may be, it is only half the story. The Canadian Arctic Resources Committee has discovered that the directive to the Department of the Environment scientists also ordered them to discontinue the preparation of questions and identification of witnesses for use by Commission Counsel as evidence before this inquiry.

As a result of this order, some of Canada's foremost specialists on the environment in the Mackenzie region, have been silent. Except for consultants to the applicant, these are the only scientists who have carried out field studies on the proposed pipeline as well as the environment of the Mackenzie for a significant period of time. The apparent attempt to exclude this information re-kindles suspiscion in the minds of many, but the decision to proceed with the pipeline has been made and that the Government is not interested in co-operating with a full and public inquiry.

This attempted exclusion from this inquiry is unthinkable. This conspiracy and silence must end. We state "attempted" exclusion because of our hope that Commission Counsel on behalf of this inquiry will insure that this evidence is brought before the Inquiry through subpoena if necessary because the Canadian Arctic Resources Committee views this evidence as crucial.For our part, we will take all steps available to insure the presence of these witnesses.

The applicant would have us believe that the problems of the construction and operation of a pipeline have been identified and largely solved or at least are capable of being resolved if only the project were allowed to proceed. We would ask that this inquiry put these assertions to a rigorous test. Throughout these hearings, Mr. Commissioner, C.A.R.C. will be questioning and leading evidence to demonstrate that the applicant is in fact experimenting on the North. It is using a host of untried technologies with undefined environmental consequences and C.A.R.C. will be examining a number of these in considerable detail before you.

Nor has the applicant provided this inquiry with a pipeline proposal sufficiently defined to insure proper review. Canadian Arctic Gas filed its application in which it claims that the route it selected was the best of all possible alternatives and has already formally applied for one

major route change and a second even more critical change for a crossing of the Mackenzie Delta is being proposed.

With these changes almost one third of the original route will have been changed. The only conclusion to be drawn is that the application is premature. Yet the applicant and others urge quick approval. They argue for haste because of a perceived natural gas shortage. It is our submission that it is just not true that there is an imminent and serious shortage of energy in Canada. It cannot be taken at face value that there is even a natural gas shortage in Canada. The 1970 report of the Alberta Energy Resources Conservation Board and evidence given before the current National Energy Board hearings on natural gas supplies by both the applicant, Canadian Arctic Gas,and Foothills Pipeline Limited show that substantial increases can be made in deliverability of gas from fields in British Columbia and Alberta. Well known Candian economists have demonstrated that even using the gas supply and demand figures of Arctic Gas there need not be any shortage in Canada before 1989. Even the applicant's own witness at the N.E.B. admitted that no northern pipeline may be needed before 1983.

No credence should be given at this inquiry to the alarmist views about the urgent need for Delta gas, especially as the National Energy Board has not completed its hearings or made its report to Parliament. They might even recommend a conservation

program aimed at leveling off consumer demand in Canada. The Honourable Donald MacDonald has told Parliament that the Federal Government's recently announced oil conservation program will eliminate the need for twelve oil sand plants by 1990. Surely then a determined conservation program for gas like the recently announced program to conserve oil, would stem the demand for natural gas in Canada. There is no reason for quick approval. This inquiry must not be deterred from its resdve to conduct a full and complete investigation of all possible consequences of the gas pipeline proposal.

The Canadian Arctic Resources Committee does not come to these hearing for or against either the idea of a Mackenzie pipeline or the Canadian Arctic Gas proposal referred to you in this inquiry. It is here to assist in a full and complete study of the issue. It is here also to urge your inquiry to make recommendations that if a pipeline is built that it will be built and constructed in an environmentally sound and socially acceptable way.

We hope as well that this inquiry will serve as a model for similar resource development projects in the north. Such a structure should provide for detailed study and public distribution of the significant information for consultation and public review prior to approval and for an on-going mechanism characterised by public accountability.

Environmental impact assessment has a well known methodology. It is first

necessary to identify environmental consequences of the proposed action in the widest sense as affecting people, animal and plant life and the overall natural system.

The next step is to classify these consequences. Some of them are major, some are minor, some have that train of secondary effects and some have synergistic or cumulative effects. In most cases these effects can be tolerated if steps are taken in advance to modify them. But sometimes these effects are irreversible. If the environmental impact falls in that category, the proper course is find an alternative.

The Canadian Arctic Resources contribution to this inquiry will be to identify these environmental effects and to examine what the applicant proposes to do about them. The applicant's witnesses will be questioned. We will follow closely the evidence given by the pipeline application assessment group and by the witnesses called by Commission Counsel.

In addition, we will have the assistance of the Northern Assessment Group which was established with support from this Commission to provide a technical and scientific review of the application for the benefit of environmental and native organizations.

The environmental concerns raised by a project of this magnitude are beyond number. Frost bulb around the pipeline, pressure on

caribou, possible disruption of breeding and staging areas of migratory birds, hazardous river crossings, denuding of gravel deposits so vital for northern communities and cumulative effects of thousands of workers and millions of tons of equipment and material.

Faced with this impact the applicant's description of its project as effecting a mere 40 square miles of land is completely unrealistic. Equally unrealistic is its attempt to isolate its project from the overall development of the north. It is now clear that the development of transportation systems for the Mackenzie Valley is undergoing rapid growth and evolution. The movement of large quantities of material and manpower required for the continuing search for oil, gas and minerals in the western Arctic and sub-arctic, has required a substantial increase in barge traffic on the Mackenzie River accompanied by channel modification to facilitate the movement of vessels of greater draft.

Air traffic. For transport of both freight and passengers has multiplied several fold. Construction of the Mackenzie Valley highway was begun in 1972 and the Dempster Highway which is nearing completion includes sections within the Mackenzie Valley just south of the Delta. There is renewed expectation that an oil pipeline may be built in MacKenzie Valley to carry oil from Alaska and the Delta region or eventually from the Delta region alone.

Apart from the proposal to transport oil and natural gas by rail, construction of a railway in the Mackenzie Valley for transporting minerals and general cargo has been proposed. Further increases in activity in this general region will require development of improved communications systems and a hydro-electric transmission system has been suggested.

There have been many references to the desirability of placing all of these proposed new or expanded facilities within a Mackenzie Valley transportation-communications corridor whose routing and design would reduce the environmental and socialogical impact on the Mackenzie Valley region, and on the people who inhabit it. It is not now clear how the Government of Canada intends to apply the corridor concept which forms an integral part of both the original pipeline guidelines issued in 1970, and the expanded guidelines issued in 1972. The fact remains that neither the corridor concept nor the potential results of allowing independent routings for each new facility has received anything more than a cursory examination.

The Canadian Arctic Resources Committee believes that a thorough study of the corridor concept is an urgent requirement which completion must precede the granting of a right-of-way of any proposed Mackenzie Valley transportation or communication facility.

Mr. Commission, maybe I may be

permitted one further comment. If approval is granted for a Mackenzie Valley Pipeline, all of the benefits of this enquiry will have been for naught if there is no effective follow-through to ensure that the safeguards recommended by this enquiry are in fact observed.

The final report of the Environmental Protection Board underlies this fact, and the Canadian Arctic Resources Committee agrees with their conclusions.

The administrative agencies required to co-ordinate the supervision of hundreds of contractors and sub-contractors at work in the Delta and Mackenzie Valley do not now exist. No matter how many laws Parliament enacts, dealing with environmental safeguards, there will always be the problem of implementation in a particular case. Judgements are made day in and day out by company and government officials in the field and in regional offices. It is the cumulative effect of these decisions that constitutes the real success or failure of environmental protection.

In the final part of C.A.R.C.'s presentation, we will present our studies of the problems faced in implementing and enforcing safeguards, together with our recommendations for new procedures to regulate major development within the framework of long-term planning.

Mr. Commissioner, these are the concepts and the principles that we would ask you to keep in mind during your deliberations. The task before you is tremendous, and the Canadian Arctic Resources

Committee pledges to you and to this enquiry its co-operation and assistance. The people of the north as well as many in the south of Canada have placed their confidence in this enquiry. Like you, Mr. Commissioner, we see these hearings as more than a technical review of a pipeline application. This is the forum that may finally open a window to the Canadian north.

Thank you.

THE CHAIRMAN: Mr. Bell?

MR. BELL: Since this is the first time I've had the pleasure of meeting you face to face, perhaps it would be appropriate if I introduced myself. My name is Glen Bell. I'm a member of the Bars of Ontario and the Northwest Territory. I will be representing the Indian Brotherhood of the Northwest Territories and the Metis Association of the Northwest Territories for the purposes of this enquiry. With me today is Mr. Gerry Sutton, the legal advisor to the Indian Brotherhood of the Northwest Territories.

Mr. Commissioner, your duties as Commissioner have already brought you north of 60 on several previous occasions, and you are no stranger to the native people of the north. Nevertheless, on behalf of the Indian Brotherhood of the Northwest Territories and the Metis Association of the Northwest Territories I would like to extend to you now a formal but nonetheless warm welcome and to offer you our best wishes for a pleasant and productive experience throughout the course of the enquiry.

Mr. Commissioner, you yourself have said that this enquiry is a study whose magnitude is without precedent in the history of our country. A study of this size is indeed well-justified. The proposed pipeline development is huge and far-reaching. Everything about it is enormous; its length, its width, its cost, its consequences for the north, and for the people of Canada. The pipelines sponsor, Canadian Arctic Gas Pipeline Limited, is a consortium of corporations which represents the larges agglomeration of private interests ever assembled in the history of Canada.

There are good grounds for both the existence and magnitude of this enquiry. Major development such as this pipeline requires close scrutiny if we are to serve properly the public interest. The Mackenzie Valley Pipeline Enquiry, independent and impartial, is the ideal forum in which to assess the weighty issues raised by the pipeline proposal.

Not only is this enquiry unprecedented in its size, its very existence in the north is unheard of. Rarely have the native people of the north been consulted in advance of large developments on their land, except in the most cursory way or after it was too late for their views to have any real effect. In the past the pattern has been for developments to be presented on a take it or leave it basis, or as a fait accompli. The natives of the north are therefore pleased to have this opportunity to participate in the assessment of this proposal.

The Metis Association and the

Indian Brotherhood are also pleased to see the sincere attentiveness with which the Commissioner has received their submissions on preliminary questions. Accordingly we enter this enquiry confident that it will be not only full, but fair.

We are especially encouraged by the Commissioner's stated intention to hold hearings in all the communities of the north which would be affected by the building of a pipeline. The Indian Brotherhood and the Metis Association, while intending to participate fully at the formal hearings, view the community hearings as being of the utmost importance to the success of this enquiry.

It is in the communities of the Mackenzie Valley, Mr. Commissioner, that you will hear most clearly the voice of the people -- people who are truly of the very land on which they live. The people know that through this enquiry they will be speaking to all Canadians, and they will speak from their hearts. They will speak of many things, not only of the pipeline but also of their lives -- the good times and the bad times, their hardships and their hopes. But most of all they will speak of their land -- the land which sustains their bodies, the land which shapes their society, the land which quickens their souls.

There, in the communities, the people will argue their case more eloquently than could any pleader. We will participate as best we can in this enquiry, but our participation should not be taken as a sign that we accept the basic assumptions

of the pipeline's proponents. Those assumptions are two:

(1) that gas in the Canadian Arctic will soon be needed in Southern Canada; and

(2) that this pipeline is inevitable.

We repeat, we do not accept these two assumptions.

The petroleum industry is claiming that we will soon be in desperate need of Arctic gas in southern Canada. There is plenty of reason for the Canadian public to be skeptical. In the first place, it is in the self-interest of the petroleum companies to make this claim. Furthermore, there are independent experts who do not agree with the oil companies. These experts say that gas from Canada's Arctic will not be needed in the south until at least 1990.

The situation in the United States may be different. That country may or may not be in need of gas from the north shore of Alaska; we are not in a position to say. What we can say, however, is that American energy needs do not justify a trans-Canadian pipeline. Indeed, the United States is now considering a trans-Alaska gas pipeline, known as the El Paso line.

Nor can we accept the assumption that the Mackenzie Valley Pipeline is the unstoppable juggernaut which its sponsors would have us believe. Canadian Arctic Gas spokesmen were recently quoted in the press as saying that the latest estimates

of the cost of the pipeline are $10 billion. This is up from an estimate last fall of $6 billion, and construction has not yet begun. Mr. Genest informed us today that the estimate should be closer to $7 billion.

Well, in spite of this confusion , it is clear that if other large energy developments provide any indication, further cost increases seem probable. An example is the Syncrude project in the Athabasca Tarsands. Costs there have already doubled, and some industry observers say they will triple before too long. The applicant, Canadian Arctic Gas, says that it wants to raise the money from the worlds' large investors and lenders. So far none of it has been found. Given the present state of the economy, a recession -- the worst recession since 1930, with no end in sight -- there must be a fair degree of doubt hanging over the prospects of raising these billions. Even the less costly Syncrude project required government aid to save it.

It is not within the terms of reference of this enquiry to look into these issues -- those relating to gas supply and demand and the financial stability of a pipeline. None of the participants will be allowed to bring in evidence on these questions. Therefore no one should think that our presence before this enquiry implies our acceptance of the assumptions that Arctic gas will soon be needed in the south or that this pipeline is inevitable.

Why then are we here? The answer, Mr. Commissioner, is quite simple. This enquiry is our one and only chance to examine in detail the pipeline proposal; it is also the best way for us to put before the people of Canada our position on the settlement of native land claims in the Northwest Territories. Indeed, we give priority to the issue relating to the land claim.

Perhaps you will recall, Mr. Commissioner, the occasion when Prime Minister Trudeau compared the Mackenzie Valley Pipeline favorably to the building of the C.P.R. What the Prime Minister neglected to mention at the time he made that comparison was the fact that for the native people in Southern Canada, the C.P.R. was a disaster. It meant the loss of their land and the slaughter of the buffalo herd upon which their livelihood depended.

It is with a view to avoiding this sort of fate that the Native people of the North will take the position before this Inquiry that there should be no pipeline before a land claims settlement. This is the position which the Metis Association and the Indian Brotherhood were instructed to take by a joint general assembly of their membership held last summer in Fort Good Hope. That meeting was the largest gathering of status and non-status Indian people ever held in the Northwest Territories.

It was also at that assembly that the Indian people of the Northwest Territories reasserted their claim to ownership of over 400,000 square miles of land. The claim has been recognized as valid by the Supreme Court of the Northwest Territories in an historic judgment of Mr. Justice William Morrow.

The legal basis of the claim rests on clear evidence that the land has been used by the Native people since time beyond memory. The Crown also claims the land. Negotiations between the Federal Government and the Native organizations over the claim are now in preparation and should get under way in the near future.

We will urge upon this Inquiry the view that the construction of a pipeline, or of any other major development for that matter, prior to the completion of a land claims settlement will have an intolerably prejudicial effect on negotiations. It is impossible to negotiate fairly over your land if the steam shovels are digging up your backyard.

We will produce evidence to show how a pipeline would interfere with the use of the land by Native people. Research now underway will enable us to transform the map of the Mackenzie district from an apparently uninhabited wilderness to a network of tracks and lines depicting extensive hunting, fishing and trapping areas. The Mackenzie River Valley is one of the areas where the use of the land by Native people is most heavily concentrated and if I may take a moment to illustrate this point, this is a map of a section of the Mackenzie River Valley around Fort Norman. Here is Fort Norman, this is the MacKenzie River.

On the map on the wall, Fort Norman appears about half way down, just across from the western tip of Great Bear Lake. This is a result of our research, Mr. Commissioner, it represents the trap lines of approximately 30% of the adult males of Fort Norman. We will be producing similar maps for the entire Mackenzie Valley, plus other parts of the Mackenzie District. We will be filing this map with the Inquiry.

Our thesis -- "No pipeline before a land claims settlement" -- is more than just a request designed to protect our bargaining position. It is the formal expression of a more fundamental issue which will be before this Inquiry. The issue is one which involves the struggle between two opposing concepts of economic development for the North.

The pipeline proposal repre-

sents the colonial philosophy of development. Opposed to this notion of Northern development is the "community" philosophy of development as exemplified by the Native land claim.

What are the characteristics of these two philosophis of development: the "colonial" philosophy and the "community" philosophy?

The colonial school of economic development is the one promoted by the American multi-national corporations and their Canadian subsidiaries. They see the North as the storehouse of resources for the industrial centres of the South -- Chicago, New York, Pittsburg, Montreal and Toronto. Oil, gas and minerals move south to these centres. The profits which they generate move south along with them. The North becomes a hinterland dependent on the south; it loses its resources and gets welfare in return. It is never permitted to develop an economic base which allows its people and particularly its native people to enjoy the benefits of equality with the residents of the industrial south.

For the Native people of the North the injustices of the "colonial" philosophy of development are cruelly multiplied and rubbed in. In the process of building a pipeline, native sociey would be dragged from a land based economy, hunting, trapping and fishing -- into a wage economy, a wage economy which would be the poor Northern cousin of the southern economy. The big petroleum companies will move in and suck dry the reserve of gas and oil from

the North. After they have gone what happens to the Native people who must continue to live here? What will be left for the owners of the land after Canadian Arctic Gas and its pipeline are just a memory? The "colonial" philosophy of development leaves them nothing, except the desolation of a ghost town.

The "colonial" philosophy of Northern development means prosperity for the multi-national corporations. But for the North it means a weak, distorted economic existence, and cultural and political retardation.

Is there an alternative to this dismal outlook? There is, and it is found in the vision of hope and dignity which characterizes the 'community' philosophy of development and which is the foundation of the land claim advanced by the Native people of the Mackenzie District.

By claiming ownership of the land, what the Native people are saying is this:

> As much as possible we want to be able to control our own destiny. We want to be the ones who decide what directions our society should take. We also want to participate in Canadian society but we want to participate as equals. It is impossible to be equal if our economic development is subordinated to the profit oriented priorities of the American multi-nationals.

Therefore, the Native people are saying, we must have a large degree of control over our own economic development. Without that

control, we will end up like our brothers and sisters on the reserves in the south: continually powerless, threatened and impoverished.

Only community ownership of the land, land which has belonged to our people for thousands of years, can give us the ability to determine and follow our own way.

These then are the two philosophies of development competing in the arena of this Inquiry, Mr. Commissioner: the "colonial" philosophy and the "community" philosophy. The decision to accept one or the other will weigh heavily in the outcome of the struggle.

The main interest of the Indian Brotherhood and the Metis Association in this Inquiry centres around the issue of the land claim; but we will also do our best to examine critically lthe application by Canadian Arctic Gas, or anyone else, for a right-of-way in the Mackenzie River Valley. We will be especially concerned with the Applicant's case as it relates to the social and economic impact of the proposed pipeline.

On the basis of material already filed with the Inquiry by Canadian Arctic Gas it will be necessary for us to assert that the Applicant, Canadian Arctic Gas, has not adequately assessed the potential impact of the pipeline and that it does not really care about the long-term effects of this project on the social fabric and economic life of the North and its Native people. To Canadian

Arctic Gas the Natives are merely a bothersome redundancy.

You do not have to look very far to find evidence of this attitude. Although the applicant has filed with the Inquiry several thousands of pages and millions of words covering a range of topics from permafrost to interest rates, the total of its statemant on the socio-economic impact of the pipeline consists of eleven pages. An examination of this so-called impact statement will show that the applicant's professed solicitude for the Native people can be reduced to a simple but hollow promise of jobs. A few hundred construction jobs which will disappear after the pipeline is built.

The hypocrisy behind the Applicant's pious phrases is further revealed if we consider that had the Native people been consulted about the kinds of jobs that they wanted, pipeline construction would have been far down the list. Development projects like this do not fit into the Native's system of priorities and thus the jobs produced are really jobs for non-natives imported from the south.

Almost invariably "colonial" developments have meant for the Native people not much more than a resource rip off and an influx of southerners. The onus is therefore on the Applicant to demonstrate how this project will be different. The 11 page socio-economic impact statement comes nowhere near satisfying this onus.

One other aspect of this Inquiry

deserves our attention before we conclude our opening remarks. It concerns a question which no doubt is on the minds of many people as we commence these hearings today. What is a realistic estimate of the time it should take to complete this Inquiry? It is impossible to predict with certainty how long this Inquiry will last. All we can say is that there is likely to be a lengthy process. There will be two types of hearings: formal hearings and community hearings. The formal hearings have been divided into several main topics each of which will be dealt with in a separate phase of the Inquiry.

In the interest of fairness to all parties, there are certain procedures which we must follow at the formal hearings. During each phase we will hear the witnesses for Canadian Arctic Gas first. Following their testimony each of the other ten participants will be given an opportunity to cross-examine these witnesses. Then each participant will be permitted to call its own witnesses, with further opportunity for cross-examination by the other participants, including the applicant. Members of the general public who wish to ask questions and offer testimony will also have to be accommodated.

Add to this the time it will take to visit the 20-odd northern communities which would be directly affected by the pipeline, plus hearings in southern centres for those members of the public who will be unable to come to Yellowknife to express their views. After the hearings, of course, the Commissioner will need time to write his report.

It will be a lengthy process, but it will be a necessary process. This pipeline would bring with it other major developments, an oil pipeline has already been announced, a highway is under construction, a railroad is being studied. Will there be a public enquiry for each of these developments? Maybe. Maybe not.

This enquiry is being asked to ascertain what will be the public interest in northern development for the next few decades. Surely we must take all the time we need now while we have

the chance. Remember, this enquiry is a study whose magnitude is unprecedented in the history of our country.

In conclusion, Mr. Commissioner, we wish to say again, welcome to the north. It is our sincere desire to assist you in whatever way we can to assure that the Mackenzie Valley Pipeline enquiry is full and fair.

As we all get to know each other better, Mr. Commissioner, I'm sure you will find, as I have that the native people of the north, are proud, self-reliant people, a people gentle in their manner, but imbued with a sense of determination born no doubt of generations of struggle with adversity. You will find them to be a diverse people, a people united in their resolve to command their own future and to live in harmony with all Canadians.

All of which is respectfully submitted.

THE CHAIRMAN: Thank you.

Just a moment. Mr. Scott, we are going to adjourn. We'll adjourn for 15 minutes for coffee and we'll reconvene at 12 o'clock sharp.

(PROCEEDINGS ADJOURNED FOR 15 MINUTES)

(PROCEEDINGS RESUMED PURSUANT TO ADJOURNMENT)

THE CHAIRMAN: Mr. Bayly?

MR. BAYLY: Mr. Commissioner, my name is John Bayly of Yellowknife, and I act as counsel for the Inuit or Eskimo people, through their organizations the Committee for the Original

People Entitlement known as COPE and the Inuit Tapirisat of Canada generally referred to as I.T.C. I.T.C. is a national organization which represents Canada's Inuit population across the entire north. COPE is a regional organization and represents the Eskimos of the Western Arctic and in particular the people of the Mackenzie Delta and the Western Arctic Islands.

COPE and I.T.C. are participating in the Mackenzie Valley Pipeline hearing because the proposed pipeline, processing plants, gathering systems and gas exploration work are being done and built, and are proposed to be done and built on lands and in waters that are traditionally, historically and are presently being used and occupied by Eskimo people in their traditional pursuits and way of life.

It is perhaps a historical piece of bad timing but the pipeline hearings will occur prior to the settlement of the Inuit land claims and that they will commence prior to formal negotiations for a land claim settlement with the Federal Government. COPE and I.T.C. have not taken the position, however, that they will refuse to participate in the Berger hearings because of this bad timing. On the other hand, the participation of COPE and I.T.C. is based on the preliminary stand that there must be no major development before the question of land claims has been settled. The Inuit emphasize that the lands and waters along the Arctic coast and in the Mackenzie Delta over which Arctic Gas seeks its right-of-way are theirs. The lands and waters already being used by gas and oil

exploration companies are theirs. No treaties have been signed, no rights have been given out, and the Canadian Courts have begun to recognize aboriginal rights. It is commonly asked of the native groups, "what do they want?"

I cannot go into details of the land claims negotiations at this time, but it is public knowledge that COPE and I.T.C. are not prepared simply to bargain their aboriginal rights for a cash settlement. The real issues in the negotiations will deal with lands and waters and the control of them. Your Commission, sir, will be looking into competing land and water uses both traditional and contemporary, and will no doubt in your recommendations design to ensure that one use of these lands and waters does not destroy the possibility of other uses.

COPE and I.T.C. take the position that the Berger enquiry is the place where they should discuss these issues as they relate to the needs and desires of the Inuit in the Mackenzie region and the Western Arctic Islands. We have all seen what has happened in the James Bay region where the Hydro Quebec Power project was partially complete before land claims negotiations got under way.

COPE and I.T.C. do not wish to see their people placed in this kind of position of having to negotiate a settlement in the shadow of a partially completed mammoth project. In this context, sir, you have stated in your preliminary rulings that you will allow evidence relating to land claims to

be led by the native groups. COPE and I.T.C. see this as an important element of the Berger enquiry because it will bring sharply into focus the extent of native uses of the lands and waters and the conflicts that will arise when these uses are compromised, changed or made impossible by development.

In order to prepare for the land claims negotiations, COPE and I.T.C. have been extremely busy. In late 1972 work was begun on the land claims legal brief , and this work is near completion. Out of that research questions have been raised about hunting, fishing and trapping rights. Legal research has been done in these areas as well. In addition, in co-operation with the Federal Government and a Hamilton, Ontario consulting firm ,COPE and I.T.C. have prepared a land use and occupancy study. This was begun in late 1973 and involved, among other things, interviews with virtually all of the Inuit hunters, fishermen and trappers in Northern Canada and the development of maps showing traditional historic and present land and water use. This study, although virtually complete, has not yet been published by the Department of Indian and Northern Affairs. We anticipate it being presented during the hearings.

More than 50 people were involved in working in this project. Late in 1974 an inventory of renewable and non-renewable resources was undertaken and is still in preparation. To prepare for these hearings, four COPE field workers have been at work since late October visiting every household in

the COPE region with the dual purpose of informing the people of the application and collecting their reactions opinions and information.

To give you some idea of the magnitude of this task, one must realize that many of the people knew nothing about the pipeline application, and that often explanations had to be made of what natural gas is, as a starting point. This work is not yet complete, and indeed it could never be done satisfactorily in the time permitted. It has progressed on schedule, however, in all the communities but Holman Island and Inuvik every household has been visited twice.

COPE and I.T.C. realize that basically this is a hearing regarding the Mackenzie Valley Pipeline. Nevertheless, and in spite of what the Minister of Indian and Northern Affairs and others have stated, it appears to be impossible to discuss this project in a vacuum. It is central to the concerns of the INuit of this region that gathering and processing facilities be discussed and enquired into because they will have a major and continuing impact on the people of this region.

Furthermore, it appears that this development is only the beginning of massive changes proposed for this part of the world. Already the Minister of Energy, Mines & Resources and others are discussing how to build oil pipelines in the Mackenzie Valley. At the same time the Mackenzie Highway makes it slow but steady progress towards the Delta.

Too often, sir, this kind of

development has been proposed, together with promises that it will shepherd native peoples into the 20th century. Too often it serves only to dislocate and disorient native people and leave them unequipped for the 20th century, stripped of their lands and waters and ability to follow their traditional pursuits once it has passed them by.

People are concerned that the Mackenzie Valley Pipeline and the development which would necessarily follow it, will have this effect on their way of life. COPE and I.T.C. therefore are participating in the hearings because of their concern that their people will be left behind and that their lands and waters will be irreparably changed. Because of this, it is important to stress again that COPE and I.T.C. take the position that the question of land claims must be settled before construction begins on the Mackenzie Valley Pipeline, or any other major development in the area. If development is to come, people wish to be ready for it and wish to participate in it. If the environment is to be altered and used in ways for which it has never been tested, the people wish to be in a position to control and police the environment in which that development takes place.

If codes of conduct or environmental control are to be written, COPE and I.T.C. wish to be there with pen in hand. If development will mean change in the way of the life of the people, COPE and I.T.C. wish to make proposals to facilitiate lasting involvement of their constituents.

COPE and I.T.C. take the position that any proposals or recommendations that do not take into account the reasonable wishes of the people, run the risk of creating future problems that may be far more costly in human economic terms than they are worth. COPE and I.T.C. plan to participate in all phases of the hearings, sir, but will rely heavily on

the Canadian Arctic Resources Committee and the Northern Assessment Group during the first three phases of these hearings. Thank you very much.

MR. VEALE: Mr. Commissioner, my name is Ron Veale from Whitehorse. I am representing the Council for Yukon Indians. Myself and Allan Luke, general counsel for the Council of Yukon Indians and will be appearing from time to time during the enquiry.

The Council for Yukon Indians represents all Indian people in the Yukon Territory with ancestral rights, and the Council was specifically organized to negotiate the land claims settlement with the Government of Canada. During the course of these negotiations the Council for Yukon Indians has insisted that no major developments take place to further prejudice their aboriginal rights.

The proposed gas pipeline is such a development and the Council is diametrically opposed to it, until a settlement is reached with the Government of Canada. In particular, the Community of Old Crow, in the northern part of Yukon Territory is most directly affected by the proposed pipeline, regardless of whether the interior route or the prime route is considered. Their life-style will be greatly affected by a pipeline, and the Council of Yukon Indians will devote its time to en sure that the views of all the residents of Old Crow will be heard at a community hearing later this year.

Mr. Commissioner, the idea of

a pipeline across the Northern Yukon is not new to the people of Old Crow. They have considered it before, but the implications to their life-style is a matter of great anxiety to them and hopefully this enquiry will add to their understanding and meet their aspirations. Thank you.

MR. TEMPLETON: Mr. Commissioner, in introducing the Environment Protection Board, perhaps I should say at the outset, that our goal is not to just make recommendations, or publish an impact assessment, but to do whatever we can, if the project goes ahead, to actually achieve environment protection. This means going much further than saying what must be done to protect the environment, or accepting promises about what will be done. It means exerting whatever influence we are able to exert to see that the environmental change brought about by the project is kept to what we consider an acceptable level.

The formation of the Environment Protection Board is a unique experiment in Canada. Can a group of engineers and scientists actually influence this project, involved as it is with big industry and big government, so that the environment protection is achieved? We do not mean to imply that many people in the industry and government are not as concerned about the environment as we are, but perhaps because of the magnitude of the numbers involved, the inertia of these organizations might prevent a reasonable degree of environment protection from being achieved.

Now, who are we? The members of the Board are: Dr. Larry Bliss, Professor of Botany at the University of Alberta and director of the Devon Island project, part of Canada's contribution to the International Biological program;

Dr. Max Britton, a renowned Arctic ecologist. Unfortunately Dr. Britton resigned from the Board in September so that he could take a full-time job with the U.S. Government. He is available to attend part of these hearings if he is required;

Mr. Donald Craik, a consulting mechanical engineer and a member of the Legislature of the Province of Manitoba, who as a former Cabinet Minister tackled many northern problems in Manitoba;

Mr. Eric Gourdeau of Quebec City, a forestry engineer and economist by training, and a friend of the natives by association, and former director of the Arctic Institute's "Man in the North" program;

Dr. Ian McTaggart-Cowan, Dean of Graduate Studies of the University of British Columbia, and well known northern ecologist;

Dr. Stanley Thomson, professor of civil engineering at the University of Alberta and former engineer on the Alaska Highway;

Dr. Norman Wilimovsky, professor of the Faculty of Graduate Studies and the Institute of Animal Resource Ecology of the University of British Columbia. He served as a member of the U.S. Atomic Energy Commission's Committee on Project Chariot and

carried out a number of other Arctic studies.

My name is Carson Templeton. I am a consulting engineer and chairman of the Board. My work in the north goes back to 1942 when I was a construction worker on the Canol Oil Pipeline from Norman Wells to Whitehorse and helped design and build the Alaska Highway -- and incidentally I did my share of the terrain degradation, the signs of which are still visible.

Now what about our goals? There were six:

1. To promote openness. We believe that all pertinent environmental information, whether in the hands of government, the applicants or university people, should be made public and discussed publicly;
2. To promote discussion of environmental matters. There is an informed public ready and able to discuss the environmental issues and all that is necessary is to present the issues and delineate the important from the less important.
3. To develop a methodology for converting environmental research into environment protection measures and controls.
4. To publish an environmental impact assessment of the proposed project.
5. To monitor the effects of the project activities on the environment if the project goes ahead.
6. To publish a post-construction evaluation.

We have in part achieved the first three goals by publishing 27 newsletters, 8 brochures, 3 interim reports, and a workshop proceedings. We achieved the fourth with the publication last September of our Environmental Impact Assessment of the project.

We have not achieved goals 5 and 6 because they lie in the future. Yet goal 5 -- monitoring the effects of project activities on the environment -- is critical. Monitoring by people who do not have a line function in the project is essential to check that the environmental protection measures are actually being implemented. Whether we do this or others is incidental.

Goal 6 is to publish a post-construction evaluation that evaluates the methods of predicting impact and the effectiveness of the environmental controls. This will follow if goal 5 is successfully achieved.

The Board's annual budget is funded by the sponsor, which at first was Alberta Gas Trunkline Limited, later Gas Arctic, and still later Canadian Arctic Gas Study Ltd. Being an autonomous body and not a firm of consultants hired to do a job for a client, the Board studied what it felt it should study within its budget limitations. The sponsor did not have the right to edit or guide our studies or our opinions and our reports. For example, we gave our reports to the printer before we gave a daft to the sponsor. The sponsor and the Board each has the right

to terminate the arrangement at any time. The path has been a rocky one, often difficult for each party, but we have survived 4 1/2 years.

The Board's terms of reference required that it study only the natural environment. Social considerations were to be left to others. However, the farther we got into our study the more we recognized that the native culture was inextricably intertwined with the natural environment, and that we just could not forget about the people. As a result, the native use of the environment was included and perhaps we've gone a little farther in some aspects. But we have considered only some of the social impacts and none of the regional economic impacts.

We have asked for and been granted status as a participant at these hearings. We do not have a lawyer to represent us. On the one hand this may make it difficult for the Commission counsel and the other participants' lawyers, having several laymen in their midst who are ignorant of and lacking sympathy with Court room terminology and procedures. On the other hand, I do not think that the impact assessment process should be come wholly a Court room exercise. I am sure, Mr. Commissioner, you have indicated in your preliminary rulings that this is not a trial.

But I feel that perhaps some of us may, in our arguing, tend to make it such. If this should happen, we all should remember an important point about the environment and man's law and it is this: man's law can and should respect the environment, but the environment cannot and will not respect man's law.

If at times the hearings appear to become a trial, then it is man's ability to plan for the future that is on trial and not the environment. In a way, the future of the environmental impact assessment process is at stake here. How well can the economists and scientists and engineers translate their studies into readily understandable impacts, specifications and controls which will lead to limiting environmental change to a predetermined level.

How well can they separate the important effectsof the project from the non-important effects and reach some kind of quantification or comparison of costs and benefits? This is not an easy job. I am sure that all of us are unhappy that we cannot be more precise. Wewould like to be able to assign a number to each impact, like dollars, to the debit and credit side of the ledger, but this cannot be done. All one can do is study the natural environment, study the proposed project description, estimate the alterations which will be caused by it and spell out the controls needed to see that the alterations are kept to the predicted levels.

This is a subjective process

that advances by study, experience and above all, honesty. There is nothing wrong with a subjective process and the fact that the environmental impact assessment process is subjective does not lessen its validity.

Perhaps I seem a little overly defensive about this, but too many people seem to expect a magic unit to appear to be used to measure environmental costs and benefits, so that an environmental statement similar to a financial statement can be drawn up. There can be no such magic unit. The application of mature judgment is the only available means of measurement.

I have only one other point and that has to do with the control of the project. I regard the matter of effective control as a major issue because without it there will be no environmental protection. Responsibility for controlling the project lies with two distinct groups: the Applicant and the Government. I have assumed that control of the project will be discussed here. Even though the four phases of the hearings which are headed Engineering and Construction, Impact on the Physical Environment, Impact on the Living Environment, and Impact on the Human Environment, do not specifically refer to it.

What I hope is that the hearings will specifically address the role of Government in controlling the project. This might very easily be overlooked but the role of Government is probably the most significant factor in

determining whether the project, if it goes ahead, is an environmental success or failure. I would like to illustrate how easily this point might be overlooked. In Volume II of our report, headed "Towards an Environmental Code", we listed the duties of the Government agency as well as those of the Applicant. This month we received the first draft of the "environmental guidelines for gas pipeline development" put out by the Ecological Protection Branch, the Environmental Protection Service, the Department of the Environment. In many places the guidelines agree very closely with what we said in our code, but there is absolutely no mention of the agency that would control the project, its duties or its responsibilities.

I bring this up only to point out that it would be very easy for people to say, "Oh, we have environmental guidelines to control the project", and at this point they usually tap you on the head and say, "It is being looked after." But as you can see by the top of my head I have been tapped quite a few times already. My efforts of getting the Federal Government to publish an environmental impact statement of the Mackenzie Valley Highway has been very hard on my head.

But the guidelines will not control the project in themselves. We may find as so many other projects in the past that enough was known about protecting the environment but it was just not done. I therefore hope that these hearings will detail the Government's role in protecting the

environment in the same detail as it does the applicant's.

On this matter of guidelines without controls I am reminded of an analogous situation that occurred in a paper mill, which I had some dealings, which is a very noisy place to work. The industry issued sound retarding earmuffs to the employees and made it a rule that the earmuffs were to be worn in the mill, but because the workers could not see an immediate need for the earmuffs, they flaunted the rule and subsequently impaired their hearing. Not until the industry policed the wearing of earmuffs, did the millworkers actually protect their hearing.

In the same way these hearings are expected to protect the social fabric and the environment of the North from degradation. Not just in the words that are spoken but in the final fact when the project is finished if it goes ahead. During these hearings all of the participants and perhaps two levels of Government will be making some promises and implying some commitments to the people of Canada. If we do not see that these commit ments and promises are actually accomplished we will have failed.

When the Board held meetings with the Native peoples at Aklavik last year, an Inuit Victor Alan spoke eloquently about Northern pollution. His definition of pollution was different than ours. He referred to it as the pollution of broken promises. I hope that when these hearings are

finished we will not have set the scene for what by Victor's definition will be the pollution of the North.

Thank you.

MR. SIGLER: Mr. Commissioner, my name is Murray Sigler, from Yellowknife. I am a member of the Alberta and Northwest Territories bar and in this Inquiry I will be appearing as Counsel for the Northwest Territories Association of Municipalities. In my remarks to day I will try to be as brief as a lawyer can be and just try to give an indication of the background of membership of the Association itself, why the Association is come to be involved in these proceedings and what that involvement and position may likely be.

I will start off by saying that the Northwest Territories Association of Municipalities was formed in 1967 and since that time it has grown and continued to act more strongly as a central co-ordinating agency for the various municipal councils in the Northwest Territories. Today, and in speaking throughout this Inquiry, the Association of Municipalities is speaking for the elected municipal governments of the City of Yellowknife, the Town of Fort Smith, the Town of Hay River, the Town of Inuvik, the Town of Pine Point, the Village of Fort Simpson, the Village of Forbisher Bay, the Hamlet of Pangnirtung, the Hamlet of Ray, Edzo, and the Hamlet of Tuktoyuktuk.

The municipal councils

which are members of the Association represent approximaely 70% of the population of the Northwest Territories and about 80% of the population of the Mackenzie district. As elsewhere in Canada all the municipal councils in the Northwest Territories are fully elected by the people in the communities. The association, and I should stress that it is not only representative of the majority of the people in the communities to be affected by any pipeline, but that representation in membership cuts across interest group and racial lines. The position of the municipalities in these proceedings is not for or against the Applicant or for or against any other participant. We are speaking only for the municipal councils elected by the people in the settlements, towns, etc., involved.

The municipalities are interested in these hearings not only from an academic point of view, not only because a pipeline development may have a great social economic impact on all the people in the Mackenzie Distric Municipalities. Apart from all that I think that the municipalities have a perhaps more important interest in these hearings and a very special one, for no matter what is said or promised or arranged or decided or negotiated or recommended or whatever, the municipal councils will be the ones, as a level of government who will be responsible for picking up the pieces and dealing with the social and economic aftermath on a community level throughout the Mackenzie District and for that matter,

throughout the Northwest Territories wherever development on a major scale, even on a smaller scale, will or is likely to occur in the future.

Perhaps it is fair to say that no other group before this Inquiry will be more concerned with the ongoing social, economic impact than will be the municipalities as represented by the Northwest Territories Association. Why the concern? Well, first of all the legislative responsibility of municipalities as set out in the Municipal Ordinance for the Northwest Territories, embraces several areas of relevance in considering the potential impact of a pipeline. These areas include: general municipal government administration, providing protection services for the communities, providing transportation services, the licensing and regulating of businesses. (Any business carrying on its operations in a municipality must be licensed), the services of providing sanitation and waste removal, providing public health providing recreation services which cannot be overlooked in the human impact and in the rapid growth of any communities that might be affected by any development, providing the utilities, of course, which is directly a concern, as far as the pipeline development goes, and very importantly, I will mention last, that the function of developing land for housing and for any other purpose within the municipal boundaries.

That's what municipalities are for, and not only involved in these hearings because of the social effects of the pipeline development, on the people, they are also involved because it is their responsibility and their burden as municipal government to do something about the effects in providing services to the residents of all these communities.

Since the job of the Municipal Council is and will continue to be, to ensure the well-being of municipal residents, it will be crucial that the municipalities be given the means to prepare for changing events and the means to solve the accompanying problems. We would ask this enquiry to give serious attention both to these problems and possible solutions in its final recommendations.

In light of the requirements and concerns of the municipalities, their involvement in these hearings will take the following format:

1. Each individual Municipal Council plans to and will be expressing directly their special local concerns at the community hearings. As with the Indian Brotherhood of the Northwest Territories and Metis Association positions that have been enunciated to you earlier, we feel that the community hearings are most important phase of this enquiry. We feel this is where the enquiry will be able to get the grassroot feelings of the people of the north, and we'll be hearing from the people themselves. We agree that this job probably will be much better done by the people themselves than

will be through any counsel.

As with some of the other participants, we have been active in Professor Jackson's Committee in trying to come up with the best format and scheduling of the community hearings. We cannot stress the importance of these community hearings to us.

2. Our second level of involvement will be with Mr. Reesor, the executive director of the Association, who will be present throughout the entire course of the formal hearings themselves, with assistance from myself as counsel when required.

3. During the fourth phase of the hearings, the Association will be represented throughout by counsel and during the fourth phase the Association will be introducing formal evidence, including the study which is now being prepared by consultants to the Association, and which will set out the common concerns and priorities felt by the municipalities regarding the proposed development. This submission will -- we feel our submission is badly required, we feel the applicant -- the application itself is lacking in its social-economic side of its material, and our submission will attempt to provide helpful information to the enquiry and from the areas we feel are important but have been missed by the applicant.

Our submission will first of all provide to the enquiry, an indication of the magnitude and nature of the impact the pipeline generated growth may be expected to have to each of these subject

municipalities.

Secondly, our submission will provide discussion and analysis of the implications of such impact.

Thirdly, we hope to provide recommendations relating to those actions which might be considered in order to minimize the negative aspects and maximize the positive aspects of anticipated municipal growth.

Fourthly, our submission will hope to provide a forum for the expression of community concerns as enunciated by the Council of each subject community.

Fifthly, we hope to give some indication of a regional-owned gas potential in various areas. Perhaps of most direct interest to the applicant, our submission will review, thoroughly analyze and recommend strategies in supplying gas to the local communities in the Mackenzie region.

Lastly, our submission will comment upon the timing of any construction of any proposal to enable the municipalities to prepare for themselves fully and properly to ensure that the people within the municipalities obtain the proper municipal services.

We do not want to be placed in a similar position as municipalities such as Fort McMurray in Alberta with the Syncrude project.

In conclusion, it is, I think, fair to suggest that all local northern groups represented

at this enquiry are rapidly developing a common frustration that many important decisions directly affecting the future of all northerners are being made or will be made elsewhere than in the north, and by people other than northerners, yet it will be us, the northerners, who will be left behind after all is said and done to salvage our lands, our communities, and our personal life-styles.

It is for this reason that all northerners are elated that these hearings are now being held in the north, and that all local individuals councils and organizations will have the opportunity to make known their legitimate concerns.

It's fair to say that this, to the people of the north at least, these hearings are being eyed as more than technical recommendations regarding pipeline right-of-way. They've become a symbol for all their common hopes, fears and aspirations regarding our growth in the future. Notwithstanding both the national and international concerns and considerations to your hearings, we are confident that this time the local people will not be overlooked or forced to take a back-seat position in the determination of their own future growth and development. It is in such a context that the Northwest Territories Association of Municipalities fits in, and I think helps explain both the basis of the concern of municipal government and their role at these hearings.

That's all I'd like to say on behalf of the Association, I'd like also to mention that

the Northwest Territories Chamber of Commerce will be represented at the fourth day of the hearings only by my partner, Mr. Searle of Yellowknife, who is unable to make the hearing today.

MR. SCOTT: Mr. Commissioner, that concludes the statements that are to be made by the continuing participants in the enquiry. I should have brought to the attention of the persons here, including the participants, that a transcript on a daily basis of what is said, not only today but on each day succeeding in which evidence is taken, is being prepared and it will be available to be read or inspected or reviewed by any member of the public at the following places:

First of all at the Commission Offices in Yellowknife, which are in the Resources Building;

At the Commission Offices in the City of Ottawa;

At the Public Library in Inuvik;

The Public Library in Whitehorse; and

The Public Libraries in Edmonton and Calgary.

In the event that on the way to complete his N.E.B. filings at Ottawa, Mr. Gibbs wishes to inspect one in Toronto, one will be available there as well.

Mr. Commissioner, tomorrow we commence with the overview evidence that will be called, subject to your preliminary rulings, by Commission counsel. We propose to begin, if you please, sir, at nine o'clock in the morning sharp. I should tell participants that -- and members of the public -- that

the following week we will commence phase 1, the commencement dates and hearing places for the other phases of the enquiry will be announced in due course as we get toward them.

That's all I have to say, Mr. Commissioner.

THE CHAIRMAN: Well, we will adjourn then until nine o'clock tomorrow. We will resume at nine o'clock sharp tomorrow morning.

(PROCEEDINGS ADJOURNED TO MARCH 4, 1975)

MACKENZIE VALLEY PIPELINE INQUIRY

IN THE MATTER OF AN APPLICATION BY CANADIAN ARCTIC GAS PIPELINE LIMITED FOR A RIGHT-OF-WAY THAT MIGHT BE GRANTED ACROSS CROWN LANDS WITHIN THE YUKON TERRITORY AND THE NORTHWEST TERRITORIES FOR THE PURPOSE OF THE PROPOSED MACKENZIE VALLEY PIPELINE

and

IN THE MATTER OF THE SOCIAL, ENVIRONMENTAL AND ECONOMIC IMPACT REGIONALLY OF THE CONSTRUCTION, OPERATION AND SUBSEQUENT ABANDONMENT OF THE ABOVE PROPOSED PIPELINE

(Before the Hon. Mr. Justice T.R. Berger, Commissioner)

Yellowknife, N.W.T.

March 4, 1975

PROCEEDINGS AT INQUIRY

VOLUME X

ALLWEST REPORTING LTD.,
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BURNABY 2, B.C.

APPEARANCES:

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Mr. Pierre Genest, Q.C. Mr. Jack Marshall, Mr. Darryl Carter, and Mr. John Steeves	for Canadian Arctic Gas Pipeline Limited;
Mr. Reginald Gibbs Q.C. Mr. Alan Hollingworth	for Foothills Pipelines Ltd.;
Mr. Russell Anthony, Prof. Alastair Lucas & Dr. Andrew Thompson	for Canadian Arctic Resources Committee;
Mr. Glen W. Bell and Mr. Gerry Sutton	for Northwest Territories Indian Brotherhood and Metis Association of the Northwest Territories;
Mr. John U. Bayly	for Inuit Tapirisat of Canada and the Committee for Original Peoples' Entitlement;
Mr. Ron Veale and Mr. Allan Luke	for Yukon Native Brotherhood;
Mr. Carson H. Templeton	for Environment Protection Board;
Mr. Murray Sigler	for Northwest Territories Association of Municipalities and Northwest Territories Chamber of Commerce

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Yellowknife, N.W.T.
March 4, 1975.

(PROCEEDINGS RESUMED PURSUANT TO ADJOURNMENT)

THE COMMISSIONER: Mr. Scott?

MR. SCOTT: Mr. Commissioner, before we commence with the overview evidence, I would advise that Mr. Anthony has something that he wishes to raise with the Commission, and I think it appropriate that he might be called on first.

MR. ANTHONY: Mr. Commissioner, I have a matter I think of some urgency. It requires that I rise and speak to you at this early date. I have advised Commission counsel yesterday evening and this morning, and I am appreciative of the consideration given in allowing this matter to be raised at this time.

In the opening statement that the Canadian Arctic Resources Committee made yesterday we outlined some of the problems that we as an intervener and as an environmentalist had experienced in obtaining some of this necessary environmental information, the difficulty in getting government documents, the inaccessibility of the Department of Environment witnesses.

Now in our attempt to make a realistic assessment of the environmental situation for in particular, phase 2, which while we have no set time-table, may arrive as early as six or eight weeks, a considerably short time, given the fact that we will be involved in the day to day activities of this Commission up to that time.

In addition, we have expressed our dismay at the learning that the Department of Environment will not be presenting to you the environmental concerns that that Department has identified through the work of its experts and such branches as the Canadian Wildlife Service and the Environmental Protection Service.

Now, Mr. Commissioner, you have advised us that this will be a full and a fair Inquiry and C.A.R.C. now finds itself in the position of being the only environmental representative on a continuing basis throughout the Inquiry, and we would find great reassurance and restore our hope and confidence that all the relevant environmental issues will be raised if this Commission was able to inform us the method and in fact the fact that the Department of Environmental witnesses who have relevant testimony to this Inquiry will be available.

Now after some considerable thought, we conclude that the participants of this Inquiry would be reassured if any of the following alternative situations could be evolved:

1. We would respectfully ask that you would instruct Commission counsel to forthwith -- I was going to say write, but the mail perhaps -- telex the Minister of the Department of Environment and then convey to the participants before you, before this Inquiry, the advice of the Minister that the Departmental experts who have relevant evidence to offer this Inquiry will be made available to this

Inquiry at government expense to present their evidence.

2. Alternatively, that this Commission could give assurance that on request of participants, Commission counsel will arrange for the presence of witnesses at the expense of Commission counsel if Commission counsel is satisfied that they have relevant evidence that should be before this Inquiry.

We are somewhat reluctant to put so much emphasis on the question and the problems of ensuring attendance of government witnesses; but it is clearly recognized that the reasonable costs of travel are significant, and that the cost of ensuring that these government witnesses attend are considerable. Should the participants be forced to rely on powers of subpoena then the normal rule would require the participants like ourselves and native organizations and other major participants to pay these witnesses their expenses. This we simply cannot do. Nor I think is it fair or even logical that an intervener such as the Canadian Arctic Resources Committee or any other native groups should be required and should bear the burden of calling a Department of Environment witness because the Department of Environment has chosen not to present its evidence itself. I think the people of Canada would be disappointed and shocked to think that the agency of the Government of Canada responsible for protecting the environment was not going to be present and the responsibility of getting this evidence was to

fall to parties such as the Canadian Arctic Resources Committee, or indeed any other participant before this Inquiry.

I would suggest, Mr. Commissioner, that unless we have some assurance that either of the alternative forms can be followed, then our efforts in this Inquiry will be frustrated. We feel strongly enough in this matter, and the matters we referred to -- other matters referred to in our opening statement about the provision of documents that we've already asked for from the Government of Canada, that we must tell you realistically what our problem and what our position is.

We suggest that it would be impossible for us to be ready to launch into phase 2, the environmental impact phase of this hearing by the end of April, which is a likely date for such evidence to come forward, unless we have these documents at the very earliest date, and unless we have some indication of the availability of the witnesses within I would say two or three weeks. At that time if it appears that we cannot adequately deal with the environmental issues we've identified as being significant, because these documents and other evidence have not been provided, it may be necessary for us to request this Commission for adjournment until this information can be available to the Inquiry, alternatively, we would have to limit our participation to those environmental issues that concern us which we can properly lead evidence independent of the work of the Department of

the Environment or information from the other parts of the Government of Canada.

We are anxious that this Inquiry move forward as quickly as possible, and we are committed, as I know this Commission is, to ensure that that takes place. But the present situation is completely unproductive, especially the government, and frustrating to those who are trying to move this matter ahead and ensure that the relative evidence is here.

We respectfully, Mr. Commissioner, therefore ask that you give these directions to Commission Counsel to insure that we have the complete evidence before us and that the evidence of the Government of Canada is forthcoming and the personnel are available to this Commission.

I am sorry to take the length of time in making that point, but we feel that this is a vital issue and we respectfully submit this for your consideration

MR. BELL: Mr. Commissioner, I think that in view of the interest that the public has and that the people that I represent have in seeing that the environmental case, the entire environmental case is before this Commission that the Indian Brotherhood of the Northwest Territories and the Metis Association of the Northwest Territories would support the Canadian Arctic Resources Committee in this request.

MR. VEALE: Mr. Commissioner, the Council for Yukon Indians also supports C.A.R.C. in this and we are relying a great deal on the evidence that they will be able to present to this Inquiry.

MR. BAYLY: And the same is true, Mr. Commissioner for C.O.P.E. and the Inuit Tapirisat.

MR. GIBBS: I have no representation to make.

MR. GENEST: I have no representations to make.

THE COMMISSIONER: Mr. Scott.

MR. SCOTT: I would like to thank Mr. Anthony for bringing to my mind early today his intention to make this request of the Commission. I would like, if you will permit, to be able to defer my respo nse to it until shortly after lunch. I do not think any harm will be done by giving us that opportunity to consider it in some detail.

MR. ANTHONY: Mr. Commissioner, I have been asked to say in public that that is fine with us and we would appreciate hearing from Commission Council at his convenience this afternoon.

MR. SCOTT: Well, Mr. Commissioner, we now commence the overview evidence. I set out yesterday, in a general way, reading from your rulings, but it was intended to include and the way that it would be conducted. It should be clearly understood that the evidence that will be brought before you in the overview is designed to provide a technical backdrop against which the position of the applicant and the intervenors, which will be led commencing next week, may be seen and examined.

The preliminary rulings determine two important matters with respect to the overview. First, that there will be no cross-examination of overview witnesses at this stage so that the matter may proceed promptly, and secondly, the determination that if any participant or interested party wishes to recall a witness who gives evidence at the overview, for cross-examination at a later or other stage of the

Inquiry, that we will arrange to effect that recall so any questions can eb put to him. That, in short is the framework of the overview evidence and I am ready to begin by calling our first witness.

Dr. Fyles.

JOHN GLADSTONE FYLES, sworn.

THE SECRETARY: Would you state your full name, please.

A John Gladstone Fyles.

DIRECT EXAMINATION BY MR. SCOTT:

Q Dr. Fyles, you are such a familiar figure to those of us in this Inquiry that I hesitate to ask you to tell us anything about yourself, but I think for the purposes of the record you might tell us something about your educational qualifications and your expertise.

MR. GENEST: Mr. Scott, we cannot hear you over here.

MR. SCOTT: I am sorry, Mr. Genest. You will read that question tomorrow morning.

A Mr. Scott inquired about my educational qualifications. I have undergraduate degrees in geology from the University of British Columbia, a Masters Degree in the same field from the University of British Columbia and a PhD. from Ohio State University with specialization in those aspects of geology that deal with the terrain, landforms, the surface of the earth, the unconsolidated soil materials and the processes that are at work on

the surface of the earth and this respect I contrast with those geologists whose main concern is with rocks and the minerals although gas is not my field.

Q Well now since your graduation with those degrees, Dr. Fyles, will you tell the Commission to what extent you have been engaged in your field and where.

A I practiced in this field for approximately 25 years as an officer of the Geological Survey of Canada. Nine field seasons have been spent in the Northwest Territories and in the Yukon.

Q Do I understand that during that nine year period you were engaged doing field investigations in your territory?

A Yes.

Q Now I also understand that from 1971 to 1973 you were the co-ordinator of Research, that the Department of Energy, Mines and Resources contributed to the Environmental Social program Northern Pipelines in the Mackenzie Valley.

A Yes.

Q And that latterly, in 1974 you served as the leader or director of the Government of Canada Pipeline Application Assessment Group.

A That is also correct.

Q Now, Dr. Fyles, I would just ask you to carry on. There will be interruptions perhaps from me or the Commissioner if there are points of clarification that are required, and I trust you'll understand that.

A I'm quite prepared to be interrupted.

Mr. Commissioner, the swearing in ceremony with the Bible in my hand has reminded me that there is a parable in the Bible about -- in which a wise man is identified as one who has sense enough to build his house upon a rock, and when the winds blow and the rain comes, the house does not fall down. I suppose we might comment paranthetically that the builder of this hotel certainly was a wise man.

Then the parable goes on to refer --

THE COMMISSIONER: To the elevators.

A The elevators are not a foundation problem. The parable goes on to comment that a foolish man would build his house upon the sand or upon the earth, and would run the risk of having some kind of a disaster, from the movable forces

of nature. I think what I want to say to you today relates to the rock and the soil and these forces which act upon the structures which man has built upon them.

Now, contrary to this Biblical injunction, most development activities of man come to rest upon the sand, upon the soil, rather than upon the rock. This is a rather deliberate thing, you know it's much easier to build things on the unconsolidated soil. You can dig into it. You can pile it up in heaps. It's generally flat rather than rock . You can use it for fill to make roads and so on. You can pour wastes and water into it and they become absorbed. Besides that, 90% of the surface of Canada is soil rather than rock.

This is all fine, and the Biblical story is all fine, in the temperate regions. In the north, however, another perameter comes upon the scene. Rock is still rock; but soil, now filled with ice and cemented together, becomes in a way a kind of rock, and some of it's comparable properties that builders and engineers are so used to dealing with in south, have disappeared, it becomes expensive to excavate. The excavated material may contain enough ice which, when melted, the material loses its strength. The excavations left behind may slump and may become a kind of seepy, messy area. It's difficult to dispose of wastes or to obtain water.

So we have a special situation in the north, which has a very real bearing upon the works of man in the north. This morning I am to provide a very general review of the physical attributes of the

region. I will deal with things which are common, a number of them common knowledge, everyday things, and perhaps I can provide a very general backdrop for the more specific things that will be said later in the day by Professor MacKay and Professor Church who will deal with more specific, more detailed topics.

I will make my remarks to a series of slides which will be shown on these two screens. I trust that we won't run into writing problems.

THE COMMISSIONER: Excuse me, Dr. Fyles, I'm having a little difficulty hearing you. Are all you gentlemen able to hear?

MR. GENEST: I have difficulty too.

THE COMMISSIONER: I think it may be that you could speak a little louder. I think another problem is there's too much noise in here and maybe if we could all pay attention to Dr. Fyles, Mr. Genest and I might have a fighting chance of hearing what he's saying.

Carry on.

A Right. I thought perhaps at the outset it was worth saying, "Where are we in Canada in the course of these hearings, and where are we today?"

The concerns that we'll be dealing with relate to that northern half of the proposed pipeline route within Canada, roughly half of the length. Now this is a rather substantial distance, and you'll note that from here to here is roughly the same as if one were to go from Vancouver over to Regina,

or from Toronto back to Winnipeg. So that it's quite a large region and we certainly can't expect it to be all the same. In the north-south direction in passing from, for instance, Inuvik to Yellowknife, one has to traverse in a north-south direction approximately the same distance as if one were to go from Yellowknife southward to Edmonton. The total north-south distance in the area that we're concerned with is almost equal to the north-south length of the province here, and perhaps it's worth noting that this is the middle part of Canada and that there is an equal section of Canada even farther north.

Of course, despite the fact that it is the middle part of Canada, in a sense, it is a northern region, a cold region, the Arctic circle passing through here, so that the northern part of the region has periods of continuous darkness and continuous -- in the winter, and continuous sunshine or light in the summer. Very cold winters and an Artic -- at least a Northern climate.

But fortunately the climate in Canada is not an east - west phenomena and for those of you who can see this particular slide, these are the temperature maps for Canada for the summer months of June, July and August with the average minimum temperature on this side and a maximum temperature on this side, and the darker colours representing warmer temperatures and the lighter colours cooler temperatures, with the yellow just about at freezing and I direct your attention to this phenomenon showing up here in the minimum temperature for June, or in the maximum temperature for August, or the minimum temperature for August, namely that in the area that we are concerned with, the temperatures are equivalent to those substantially farther south if one were to go east in Canada. If one were to go directly eastward from this area would pass into a colder region.

So we have a warming distribution of the temperatures in the summer, into the region that we are concerned with, so it is not quite so arctic as one might think.

Now, this trend is illustrated by the permafrost map of Canada, a subject which Professor McKay will deal with in some detail later and you will note that the area we are concerned about Great Slave lake here and the Great Bear Lake here, and the coast here, lies within the permafrost region, but the boundaries between the various kinds of permafrost, the more severe in the north and less severe in the south, trend, quite a

northerly trend, so that we have conditions in our study region, much of our study region equivalent to those substantially south in Manitoba, Ontario, Quebec and the kind of intense situation you might find at this same latitude farther east is only found in the coastal zone.

Now, vegetation is another indicator of climate and in this map shown on the far screen you see the vegetation regions of Canada and again the same trend with the forest extending well down the Mackenzie Valley and the northern limit of trees only along the coast, whereas farther east of course you have the barren lands coming much farther south.

So, in the southern part of the region they have quite large forests and it is only as we get very close to the coast that you get this treeline situation and even at the outer -- outermost land along the coast, there is still a fairly substantial cover of green growing things. The Rock Desert with scattered plant assemblages is not a characteristic of the lowland area along the Mackenzie Valley, but rather is a function of the Arctic Islands and the mountain regions to the west of the Mackenzie Valley.

Within our region, of course, climate is not uniform and I am not going to try and go into any detail, but this map illustrates a very distinct zonation of climate, but along the Mackenzie Valley a progressive change from south to north to a

whole series of zones and then more severe situation to the east and in the mountains to the west and the zone along the coast somewhat modified by the presence of the sea.

Another -- there are many aspects of climate that I could talk about and I do not propose to go on to a lot of them. One though that I will mention briefly is the matter of precipitation. This map shows the number of days in the year that there is precipitation in Canada and you will note that the region that we are concerned with, like the prairies, lies within one of the regions with the smaller amount of precipitation. The darker colours are those of high precipitation, and the lightest colour are those with -- large numbers of days with precipitation and the light colours are those with small number of days with precipitation.

Now, of course, this does not mean to say that the region is dry. Much of the ground surface in the summer is very wet indeed. This is partly a function of the low temperatures and partly a function of the presence of an impermiable permafrost barrier a very short distance below the surface which prevents water from draining into the ground.

Now, let us look at the physical attributes of the region. This map of Canada shows the Mackenzie Valley in green and Great Slave Lake through to the coast and on a larger scale you can see it better. The dark green colour is -- represents areas within 500 feet of sea level. The paler green

is area within a thousand feet of sea level, so we have a large low region with high mountains to the east and a plateau region -- to the west, a plateau region to the east and a substantial lowland along the coast.

The pale blue area lies less than 500 feet below sea level so that we have a lowland along the coast which is much broader than that which shows above the sea.

Through this region, of course, flows the Mackenzie River and this map shows the river discharge and provides us with an idea of how large the Mackenzie is compared with the other rivers of Canada and how it ranks with the St. Lawrence in its magnitude. It is truly one of the great rivers of the world with many and contrasting moods.

Canada may be divided into a number of distinct landscape units or areas of contrasting character, so we have the snow, the Canadian Shield shown here in pink, the corridor, the mountains shown in blue, the interior plains shown in yellow, and what's less familiar to most people, Arctic coastal plain extending along the west side of the Artic Islands and into Alaska, and as I said a few moments ago, it's got a very bad submerged portion.

Now of course, we don't have to go very far outside the door to see what the Canadian Shield is like. It's the same whether one is in Ottawa, or Loon Lake, or North Bay, or a lot of other places, or in the barren regions up near Coppermine. An area of hard rocks, little knobby hills, all kinds; of course the mountains come in all sizes and shapes with rocks inclined in different directions. The interior plains, the yellow area, if one were to strip the vegetation you could imagine yourself somewhere near Saskatoon or Edmonton or as in this case, Arctic Red, an area of low relief and flat line , soft rocks. Or perhaps one might imagine oneself in the Niagara Gorge instead of in the ramparts of the Mackenzie. There are great similarities in the interior plains region, whether you're here or right around here.

The coastal lowland region up in here is quite different, although in a way it is an extension of the interior plains. You can see it perhaps better in that blown-up section of the map, lying astride the mouth of the Mackenzie River. Here,

for instance, we have a view at Shingle Point west of the mouth of the Mackenzie River with the coast plain about 10 miles wide and the Richardson Mountains beyond. Or looking along Richards Island, one of the minor channels in the Mackenzie Delta, the Delta on this side and the rolling hills of the lowlands on the other.

Now for the most part the Mackenzie River lies within the interior plains, but in this area in the vicinity of Rigley to Norman Wells, the river ducks in behind an outer range of mountains. Here at Norman Wells, looking north, you see this outer range of mountains, the river, and what is called the Mackenzie Plain, which lies along the river and between the outer range of mountains and the main Mackenzie Mountains.

Looking again at these mountains from above the river, you can see the relatively steep sided escarpments, a series of ridges. The Mackenzie Plain along the river where Port Norman and Norman Wells are situated is partly underlain by a soft rocks, sands, and shales, and partly by the limestones which form the mountains which are dissolved in sink-holes such as this.

The area I've been talking about, of course, is in here where the mountains go out beyond the Mackenzie River and where the river and the pipeline route are confined. Now this map is like the last one, showing the physiographic regions but it is really a part of the Mineral Map of Canada. Just to

refresh our memory of such matters, of course numbers of mines of mineral deposits in this shield area whether one is in Northwest Territories or Ontario or Quebec, likewise numerous mines & mineralized areas within the mountains of the Cordilla.

The interior plain has a few mines and mineral deposits, such as the one at Pine Point and hopefully there will be other Pine Points in the future, but of much greater interest at this moment is the matter of oil and gas reserves. Here is the northern end of the Athabasca Tar Sands and some of these blue and red spots marked "Oil and Gas Fields" in Alberta. The black circles which we plotted on the map here represent the presently known discoveries of oil and gas in the Northwest Territories. You see that to a very large degree they lie within the interior plains, in the coastal plains to the north, and on the fringe of the -- in part on the outer edge of the mountains here and in the Eagle Plains there. So we have a shot of the delta showing the seismic activity, one of the oil well rigs, and the coming back down to Norman Wells, there is a refinery at Norman Wells which is an oil field within this part of the mountains and not in the interior plains.

Now I'll change my subject at this point and start talking, instead, about the larger features of the earth and deep in the earth, some of the surface features. This photograph, of course, is not of the Mackenzie Valley, it's one of the ice-caps in the Arctic Islands, and I'd like to remind you that

all of Canada with the exception of this part of the Yukon, was some 15,000 years ago, down to 10,000 years ago covered by a great ice sheet that extended from the Atlantic Coast to the Arctic Coast over in here. This ice sheet had some substantial effect upon the land surface. Of course, there are striking land forms resulting from the movement of the ice across the ground, but more particularly important to us, the ice movement created materials which form the surface of the earth. This is a stony glacial till which is the rubble picked up and left behind by the glacier as it moved actoss all of Canada. I've chosen rather a stony example because many photographs we have of glacial till look like a dirty grey concrete, so that they're not all as bouldly as this and I trust that construction in the Mackenzie Valley will not encounter too many things of this nature. They are known to be present. Glaciers also have rivers associated with them which leave deposits of gravel in all sorts of opportune and inopportune places, and are used extensively in construction throughout the country and in -- and will be used in the Mackenzie Valley as well as elsewhere.

Now one of the things associated with the ice sheet was a complete change in the drainage. Of course the ice covered land so the river systems came to an end and stopped. Then as the ice retreated, lakes formed in various places, partly the result of damming of drainage and partly as a result of depression of the land surface by the weight of the

ice. In this map the green colors show areas of Canada which, at one time or another, were under lakes after or during retreat of the ice sheet.

Now these lakes were some of them very large, some of them very small, and the thing I'd like to bring out at this moment is the clays which were deposited on the land surface at the bottom of these lakes. Now this sample of these layers about an inch thick, looks very innocent and quite solid. These clays may be quite considerable thickness, several tens of feet in thickness, and they're very wide-spread in Canada. But solid though the material may look, they are the source of many engineering foundation problems, whether one is at Winnipeg, Regina or here at Fort Simpson where part of the river bank has slumped away through the instability of these clays.

This map shows the distribution of glacial lake clays in the southern part of the Mackenzie Valley. Here is Fort Simpson, and the west end of Great Slave Lake is approximately here, so there is a substantial area of clay shown in blue through into here and up in the vicinity of Rigley. Along here, Norman Wells and south of Fort Good Hope, and even in the region of Artic Red.

Now, of course, after -- sorry, I have to reverse this -- when the ice sheet covered the whole region of course there was no vegetation at all except in those areas that were not ice covered. Thre were no plants and no animals so that as the ice retreated the animals, the vegetation and the fish and so on migrated back in and some elements of the distribution of these even today reflect the pattern of remigration into the country.

With the disappearance of the ice, all the normal processes that act on the land surface by wind and water and slope movement took over. So of course the rivers like the Mackenzie here at Fort Rigley, cut down below the level of the plain left behind by the glacier and small streams eroded gulleys of all shapes and sizes.

Because of the coldness of the climate, the ground in substantial areas became permanently frozen, with ice in it and ice ridges in certain areas worked their way down from the ground surface. These form interesting patterns over the landscape throughout the area that we are concerned with and each of these cracks will have an ice wedge beneath it or has had an ice wedge beneath it in the past which has now melted out as a result in changes in climate.

Here is an abandoned air-strip and you can see the pattern of the ice wedge is retained even though the area has been cleared and used by man.

On flat ground all sorts of hummocks, knobs and miscellaneous things of this type have developed through frost movement in the active layer that seasonally develops above the permafrost surface.

On slopes, gentle slopes such as this, the process is one of general down slope creep and differential movements lead to a striping of the ground with joining linear bands of slightly different character and supporting slightly different vegetation and with a different drainage characteristics.

This photograph at the top is here and the ground slopes away and down this way. Of course, on steeper slopes things have a tendency to fall down hill so one gets rubble of various kinds. This thing is a rock glacier which I will not try and explain today, it will take too much time, but it is a distinctive slope form of rock rubble and then of course there are many kinds of earth failures on slopes and river banks.

Now, one thing that is of considerable importance in the surface of the land of the region, of course is the development of vegetation, the development of soils and the build up throughout a great, a large part of this region of a layer of organic matter or peat. In some places only a few inches in thickness, but in other places in the order of more than ten feet. Now, this of course changes the character of the surface material. It of

course absorbs a lot of water, it is sort of like an intermatted mesh of things that hang together and retard erosion and of course is an insulating blanket which changes the whole temperature regime of the ground. The development of this organic material in layers of different thickness creates a distinctive landscape. This is entirely a peat landscape with the ridges such as this, frozen peat and of course the ponds in between and the fen areas unfrozen.

If one looks at this from the ground or standing in one of the unfrozen fen areas and looking to a frozen ridge of peat, roughly ten feet higher than a person standing on top and if one were to dig a trench through that ridge that a person was standing on, from one of the fen depressions on one side or the other, it would look something like this with a whole series of layers of peat down on to the mineral soil. In the middle of the summer, or early in the summer, the ground surface would be thawed something like so -- with a remnant of the winter ice or frost in the ground underneath the fen, but no further frozen material, but beneath the mound of frozen peat of course the continuous frozen ground, down to some unspecified depths below.

Now, I have tried to show you in these slides that the land surface is a dynamic one with various active processes taking place which man in his works can take advantage of or run counter

to or accelerate or decelerate, depending on his successes and failures.

Now, we have been talking about the area that was covered by the glacier, the ice sheet, chiefly along the Mackenzie Valley and I would like to just briefly say something about this light area, the unglaciated area, where the normal processes of rivers and wind and slope movement, freezing and thawing have gone on for many millenia.

Here on the eastern flank -- sorry --

THE COMMISSIONER: Excuse me Dr. Fyles. The leg of the proposed pipeline from Prudhoe Bay to Travaillant lake will pass over the unglaciated area, would it?

A Yes, that is correct. The eastern -- the western edge of the glaciated area lies along the eastern edge of the mountains and down to about into here, like so, so that the interior route crosses into the unglaciated area. The slide on my -- on this side, is roughly along the mountain front here and you can see the glacial materials of the lowlands, they cover overburden and drift and the unglaciated mountains beyond where the surface materials all are simply rock rubble.

Now, if one passes across this -- the Richardson Mountains into these intermountain basins, we come upon quite a different landscape. Here there are broad sloping benches which are called pediments which have developed as a result

of water erosion and down slope creep on the bedrock surface. Here is another view of the same sort of thing and characteristically high up near the mountains these are covered by quite coarse rubble derived from the bedrock, only a few feet in thickness, and as one comes lower and lower down into the basin the over burden material is progressively thicker and finer textured and of course will contain more ground ice and then through these benches the rivers are cut, valleys of various sizes and depths and down in the floors of the basins such as here at Old Crow, the Old Crow Flats, they are thick, fine-grained ice ridge sediments, thick cover of peat on the top and of course many lakes.

Now, -- so that is the unglaciated area in a very brief nutshell.

Now, let's look equally briefly at the Yukon portion of the Coastal Plain and then at the other part of the Coastal Plain. so if we go across the mountains to the coast and look back, this low plain, not very much relief, on the coast, muddy slopes or sandy slopes cut into by the sea, much ice in the material, bedrock not exposed generally on the coast and of course in the summer time you still have this sea of ice hanging fairly close in.

Many of the rivers, particularly in the western part and even more particularly in the western Canadian part here, more particularly in Alaska, flow on broad, flat flood plains in a braided

pattern with the channels changing continuously in position and size as the season changes. This white thing down here is the mid-summer remnant of an icing which developed during the winter, through water continuing to move through the gravels of the river bed and coming to the surface certain places and continuing to flow and freeze on the surface buildup. A large body of ice which will last through a good part of the summer. These are quite a common feature of these braided river beds.

Of course, not all of the rivers are braided like that, and here is a segment of the Fort Pine caribou herd migrating through this area.

Now, if we go over to the opposite side of the mouth of the Mackenzie, we have the other part of the coastal plain and here we are on the Tuk peninsula approximately up there. Now, this is an aerial view of Tuktoyaktuk here with the Dew Line facing over there and it gives the impression of a country almost awash, low hills, and a coast which is eroding in certain places and building out bars and spits in other places. This photograph was taken looking eastward at midnight, so you can see the long shadows of the pingos pointing almost due south.

The, much of the Tuk Peninsula consists of unconsolidated sands in the portion that's exposed above the sea, with the bed-rock well down below, below sea level. Lakes are exceedingly numerous, much of the land is flat, and these lakes are continuously changing in shape and size by processes of lake enlargement, the melting of ice around the edges of the lakes in the soil, because of the warmth of the water against the margins so that the lake boundaries move outwards through the melting of the ground ice until a drainage point is encountered and then lakes will drain, and on the bottom of those lake beds, of course, other ponds will form which will go through another cycle of this history. So it is a continuous process of change.

I'm sure Dr. MacKay will deal with this perhaps more later in his talk. Of course, as the unfrozen material in the lake bed is exposed to the air, the frost penetrates in from the surface and pressures build up which may lead to pingos in some of the beds of these drained lakes.

The coast, as I said, is rapidly eroding in some places, such as this muddy cliff, and building beach bars in other places, The coast is an accident of sea level. I would draw your attention again to this map and this zone which lies only less than 500 feet below sea level. Somewhere on one of these things -- that's the one -- I recall the matter of glaciation. Here we are in the coast -- the Northwest Territories-Yukon coast -- and at the maximum

of glaciation, there is a great body of ice extending off in this direction, across the continent of North America and on other northern lands. These ice sheets extracted a lot of water from the sea with the result that the sea level is lower, so at the time when the area was covered by the ice sheet, the ocean level was lower and a substantial part of the coastal plain was exposed above the sea. Then as the ice melted, of course, the sea rose again across the coastal plain and we now have former land which now lies off-shore from the Arctic coast.

Now I would now like to -- before I move this I would like to draw your attention to this lobe here, which marks the mouth of the Mackenzie River, and there was a rather major lobe of the glacier which extended down a deep valley, which is now occupied by the mouth of the Mackenzie. So in this slide we have the Yukon coastal plain here which is the Herschel Island and the Alaska border approximately here, and Richards Island and Tuk Peninsula over on this side, and between this valley which can be traced outward to the continental slope, a valley some 30-40 miles wide, and those of you who are close enough can see figures on this thing, indicating the thickness of the Mackenzie Delta sediments across, the sea bottom is flat, almost flat, and from sounding methods, we have demonstrated great thickness of sediments across here which has been used to demonstrate the seaward continuation of this valley, and of course this part of it has still not been filled in by the river. So this is the Mackenzie Delta, the

outer part with the eroded slopes of the old valley on both sides. I think the next slide shows this view of this -- no, sorry, this is earth's photograph showing the Mackenzie Delta, with the Tuk Peninsula and other parts of the coastal plain here, the Yukon coastal plain there, and the front of the Richardson Mountains here, and the muddy waters of the Mackenzie showing up as pale blue, and these channels going out there and dumping mud out into the bay and mud coming out this way and sweeping off into this direction.

Now as I was saying a moment ago, the next slide shows the eastern edge of the delta depression, here an ice-snow road on the east channel with the abandoned settlement of Ranger Depot. and the front of the Cariboo Hills a few hundred feet in height. Here we are in the outer part of the delta looking sort of southward and westward to the Richardson Mountains off to the west. You can see the steep front of the mountains which marks the western edge of the delta, and of course the typical pattern of river channels and lakes which are so commonly portrayed as a typical photograph of the Mackenzie Delta, the delta behaving sort of like a sponge or sieve and as water levels rise during flood season, water goes into the small channels and thus takes mud into the lakes and then during lower water periods the flow is reversed.

The higher or inland portions of the delta are forrested and the river banks which vary in height, depending on the season of the year,

are under-cut by the river; whereas in the outermost part of the delta new sediment and new land is added each year as the spring floods bring down more and more silty mud. This is Shallow Bay out in here.

With that, Mr. Commissioner, I think perhaps I should not take the subject any farther.

THE COMMISSIONER: Thank you very much, Dr. Fyles.

(WITNESS ASIDE)

MR. SCOTT: Mr. Commissioner, the carol of slides has to be changed, so could I suggest a 10 or 15-minute adjournment while that is done?

(PROCEEDINGS ADJOURNED AT 9:55 A.M.)

(PROCEEDINGS RESUMED PURSUANT TO ADJOURNMENT)

MR. SCOTT: Mr. Commissioner, our next overview witness is Dr. J. Ross McKay, a Professor of the Department of geography in the University of British Columbia. Dr. McKay?

JOHN ROSS McKAY, sworn:

THE SECRETARY: Will you state your full name, please?

THE WITNESS: John Ross McKay.

DIRECT EXAMINATION BY MR. SCOTT: Dr. McKay, I understand you are a Professor of the Department of Geography in the University of British Columbia, is that correct?

A That is correct.

Q And that you are a Ph.D. in the University of Montreal.

A That is correct.

Q What was the subject or the discipline of your Ph.D?

A In Geography, in the study of geomorphology.

Q Yes. I understand that commencing in 1946 until 1949 you were on the staff in that subject at McGill University.

A That is correct.

Q And since then, since 1949 and currently you are at the University of British Columbia in that discipline.

A That is correct, yes.

Q And that at the University of British Columbia you are presently teaching two courses on the subject of permafrost.

A That is correct.

Q One course would be enough for us.

(LAUGHTER)

A It might well be.

Q Dr. McKay, I understand that for 20 full seasons you have been inthe Western Arctic three months each, engaged in field work, is that correct?

A That is correct.

Q What is the nature of the field work that you've been doing in brief?

A Primarily a study of the origin of permafrost and the ground ice in it, along the Mackenzie Valley and the Western Arctic coast.

Q Yes,and I take it that in that period of time you have taken a series of field trips down the Mackenzie River to the coast.

A Yes, we worked about six times down the full length of the Mackenzie River.

Q Yes. I also understand, doctor, that you have served on numerous national and international committees on matters connected with permafrost.

A That is correct, yes.

Q And that in addition to that work your publications and your main research

interest for many years have been associated with permafrost with specific reference to the origin of ground ice.

A That is correct.

Q Now, doctor, would you carry on, if you please?

A Thank you. Mr. Commissioner, ladies and gentlemen, in today's overview hearing on the physical environment of the Northern Yukon, the Mackenzie Valley, Dr. Fyles has placed the region in its appropriate physiographic, geologic and climatic setting. I have been asked to give an overview of permafrost, omitting the hydrologic, geotechnical and ecologic aspect which will be discussed by others in subsequent sessions.

Permafrost is a clearly defined technical word. It is often used rather incorrectly as being synonymous with ice. Permafrost refers to a temperature condition of the ground.

THE COMMISSIONER: Excuse me, Dr. McKay. Are you gentlemen able to hear this?

MR. GENEST: I am having difficulty, doctor. Perhaps it's my own ears.

THE COMMISSIONER: Well, this is a public hearing. Excuse me, Dr. McKay, I'm sorry to interrupt you. Are you people, members of the public, able to hear what is being said?

THE PUBLIC (IN CHORUS): Yes.

THE COMMISSIONER: Well, it may be your own ears.

(LAUGHTER)

THE COMMISSIONER: Well, we'll carry on and I really would appreciate it if we could all give our attention to Dr. McKay and then I think we'll all be able to hear you. Carry on, sir.

A Thank you. Permafrost refers to a temperature condition of the ground in which the temperature below zero degrees Celsius or 32 degrees Fahrenheit has existed for a long time, a period which may extend from 2 to tens of thousands of years. The word "permafrost", then, is defined solely upon two criteria: namely a temperature below zero degrees Celsius and a minimum age measured in years. It is most important to stress the fact that the presence or absence of ice is not relevant to the definition of permafrost. This distinction is essential t o our discussion. For instance, a permafrost site at Yellowknife can be an ice-free bedrock. That is up in there. An off-shore permafrost site along the Yukon coast may be in sea bottom sediments where the pore water being saline has no ice at minus 5 Celsius. Other sites can have ice, but no excess water is produced when permafrost is thawed. By "excess water" is merely meant the following: If we take a glass and we fill that glass with soil and if we thaw the soil in the glass, if the soil is moist there is no excess water; but if there is free water or stagnant water above the soil then there is excess water.

So examples where very little excess water are the pore ice of sands and gravels clays with a high unfrozen pore water content. That is

clays can be frozen at below zero Celsius and still have the pore water unfrozen. Other sites can have abundant excess ice so that a large surplus of water is released when permafrost thaws. Examples are the ice ridges along the Yukon coast.

Segregated ice which underlies nearly half of the Townsite of Inuvik, pingo and obtrusive ice near Tuktoyaktuk, and ice ridge organic peaks in many parts of the Mackenzie Valley. Yet permafrost includes all of the preceding examples. It is obvious, therefore, that if permafrost and ice-free bedrock at Yellowknife is warmed to above zero degrees, nothing happens to the properties of the rock, because there is no face change from ice to water.

What if a permafrost site at Yellowknife contains excess ice? Thaw would lead to surplus water, possible instability and subsidence. Consequently our concern today is not with permafrost in general but specifically with the role of ground ice in permafrost. I should like to stress most emphatically that although I will be concentrating on ground ice, there are very extensive areas of the Northern Yukon and Mackenzie Valley where ground ice is very sparse. But these areas are omitted from the present discussion.

Origin and distribution of permafrost. Permafrost can only occur at sites where the mean annual ground temperature is below zero Celsius. This slide shows approximate mean annual ground temperature, the lowest about minus 9 Celsius or 15

degrees Fahrenheit are along the coast, whereas some temperatures above zero are encountered at Fort Simpson, Fort Providence, and Yellowknife. For example, along the coast the mean annual ground temperatures are above minus 8 or minus 9. As we come down, minus 4, minus 4, minus 2, minus 3, minus 1, and we come down to the Fort Simpson-Yellowknife area, some of the temperatures are positive and some of them are negative. Ground temperatures are, of course, a direct response to air temperatures. In general, mean annual air temperatures are from 3 to 5 degrees colder than the corresponding ground temperatures. The winter snow cover helps to insulate the ground and keep it warmer than the air. That is in the Mackenzie Valley and the Western Arctic coast, the air temperatures are about four degrees colder than the ground temperature, and as air temperatures change, ground temperatures change and permafrost is the response to air temperatures.

This slide shows the generalized temperature changes with depth at a permafrost site. The vertical latches indicate depth of the ground. The horizontal latches is temperature with positive or above freezing temperatures on the right, and negative or below freezing temperatures on the left. The two curves are for the maximum and minimum temperatures reached at any given site.

The diagonal line is the mean annual ground temperature which decreases with depth. That is this line indicates depth,across the top is temperature, so this would be the temperature at the surface of the ground and as we go down in depth, the temperature tends to rise. Where that temperature curves crosses zero, that is the bottom of permafrost. This is the maximum temperature reached in the ground, that is the minimum, where that curve crosses zero, the ground above that depth thaws in the summer, refreezes in the winter and that top zone is known as the active layer.

At a depth of about 50 feet, where the two curves meet, the year round temperature is nearly constant. That is at that point there which is roughly 50 feet where the maximum and minimum temperature curves meet, the temperature is nearly constant the year round. The temperature at this depth here is used to delimit the boundary between continuous and discontinuous permafrost. The boundary is along the average position of the -5 Celsius mean annual isotherm. Areas of continuous permafrost are to the north, discontinuous to the south.

A permafrost map can be very misleading if it is literally interpreted and if an allowance is not made for the great variability of permafrost in a small area, such as a square mile. for example, Dr. R.J. E. Brown of the National Research Council has measured some ground temperatures at Yellowknife and this is depth in meters, five, ten, so

that is 15 feet -- 30 feet. This is temperature along the bottom, so this is zero in there, - 1, + 1. We see that the range in ground temperature at Yellowknife is more than two degrees Celsius with sites of spruce and sedge having permafrost, these two sites here are in permafrost whereas the other three sites in a burned area, in an area of granite, and glacial till which Dr. Fyles mentioned, have no permafrost. This indicates the variability of permafrost at any given site.

Passing on then to ground ice. A very generalized classification of ground ice is shown in the slide. On the left hand column is the water source, in the centre column the transfer process which brings water to the freezing site and on the right examples such as an ice wedge, pore ice, cavity ice, pingo ice and segregated ice. When surface water trickles into vertical cracks and freezes, ice wedges form. That is if we take surface water, moved it by gravity into vertical cracks, we have ice wedges. When subsurface water freezes in place, pore ice forms. If you take sub-surface water, we freeze it in place, we have pore ice. When sub-surface water moves by vapor diffusion we have cavity ice. When subsurface water moves under a pressure potential we have pingo ice and under a thermal potential we have segregated ice. We today are most concerned with ice wedges and segregated ice because of their high ice content. Pore ice and pingo ice are of lesser interest than cavity

ice which will not be discussed which is only, unfortunately, I suppose of academic interest.

The ice types to be considered in sequence then are ice wedges at the top, pore ice, pingo ice and segregated ice.

THE COMMISSIONER: Mr. Scott, that is a slide that I think in due course should be marked and appear in the transcript. I only make that comment now so that you and the reporter will understand that. Carry on Sir, please.

(SLIDE MARKED EXHIBIT 49)

A The ice wedge on the left is ten feet wide at the top and 25 feet deep. The ice wedge is composed of nearly pure ice. Another ice wedge seen in the oblique section is on the right. there is one on the left and there is the one on the right. The ice wedge exposures along a coastal bluff at Garry Island one hundred miles northwest of Inuvik.

In flat areas ice wedges produce a polygmal pattern where troughs delimit the ice wedges. Under each one of these troughs there is an ice wedge similar to the one in the preceding slide. It might be smaller, it might possibly be larger. The polygon shown here are roughly about perhaps one-quarter the area of this room. Polygmal patterns are a good sign of underlying ice wedges, however, on hill slopes steeper than about four degrees, down slope soil movement

tends to mask trough development and so the presence of ice wedges may not be visually evident even though they are abundant. We can see ice wedges here, but on the hill slope back there they are also present, but not easily, visually detected.

Ice wedges are formed by thermal contraction of the ground in winter and by infilling by melt waters in May and June. During the late winter, usually in February, cracks may open in the ground and penetrate downwards as much as 15 feet. So, here then are ice wedge cracks exposed obviously by the removal of snow.

The cracks begin to close in the spring, but if snow melt enters the crack before it is completely closed, a thin vertical ice vein becomes sealed in permafrost. What happens then is that the snow melts, water runs down that crack, since that crack penetrates into permafrost, that portion of the ice vein that freezes there is preserved in permafrost.

Repeated cracking and infilling along this zone of weakness may produce over some thousands of years ice wedges many feet in width, so here we have an ice wedge forming in the first winter, water runs down there and freezes, the first fall we have ice preserved in permafrost, the active layer thaws, this process cycles on then for some thousands of years, and in a thousand and one we have an ice wedge crack and thousand and two there is the ice wedge. This is the mechanism of ice wedge growth.

THE COMMISSIONER: Would that slide be marked too in due course.

(SLIDE MARKED EXHIBIT 50)

A Actively growing ice wedges are numerous along the Yukon Coast, the outer Mackenzie Delta and Richards Island. In this area in there. Ice wedges are also fairly numerous south to Arctic Red River, but at the present time probably most are not growing. There are ice wedges here but most are probably inactive. Ice wedges become fewer and fewer southwards and not many have been seen south of Fort Norman although a few do occur.

THE COMMISSIONER: That slide as well.

(SLIDE MARKED EXHIBIT 51)

A Ice wedges are quite stable features under normal conditions. For instance, ice wedges can continue to grow even if fields of water occupy the troughs every summer as is shown in the slide. However, ice wedges are very susceptible to thermal erosion if there is a sustained flow and the crux is a sustained flow of water through the troughs above the ice wedges.

To illustrate, about every two years a large lake on either Richards Island or Tuk Peninsula becomes drained naturally by the thermal erosion of ice wedges at its outlet. This

slide shows one such lake that drained on Richard's Island in 1964 and here is the drained lake, Dr. Fyles showed a picture of a drained lake. From there to there there is about a half a mile, and the lake was drained by overflow through there and the over flow channeled through ice wedges and drained the lake.

In every single example that we have examined in the field drainage has occurred because stream flow was diverted by natural means through an ice wedge system.

This slide shows the results of ice wedge erosion for a lake which drained last June in 1974. There is a man for scale,and there is the drainage channel. The large gully has not resulted from soil erosion, but from thermal erosion of ice wedge ice.

The sustained flow was derived from snow melt and lake-over flow last May and June. The gulley will probably become stabilized in the next several years.

THE COMMISSIONER: Excuse me, Dr. McKay, how long did it take for that gulley to become established?

A I think that would have eroded through in maybe two weeks. Pore ice is the ice which bonds or cements soil particles such as sand grains together. This is a slide that shows lens ice here and pore ice. For scale, this would be about two inches across, so this is pore ice and that is segregated ice. Here we see the soil layers bonded by pore ice with ice lenses in between. If the pore ice just fills the intestices and yields no excess water when thawed, then sites of pore ice are usually not problem areas. Pore ice is characteristic of sandy areas wherever they tend to occur.

Although pingo ice is not of direct importance, an understanding of the mechanism of pingo growth is relevant to our discussion, and here is a pinto 120 feet high, and it has 120 feet of ice below it, and there is the ice of a pingo about 25 feet high. This slide shows the distribution of the 1,500 pingos north of Inuvik. None are known to occur to the south. Nearly ever pingo has grown in the bottom of a great lake . As a rough estimate, pingos grow in only about one-quarter of the Great Lakes, therefore probably 5,000 or more lakes have

drained naturally in the past 10,000 years, that is since glaciation for the 1,500 pingos to grow. A substantial proportion of the lakes have been drained by iceridge erosion.

THE COMMISSIONER: Mark that as an exhibit.

(SLIDE MARKED EXHIBIT # 52)

A In any permafrost area all large deep lakes and rivers have an unfrozen pool of water at the bottom. If we take a large lake and it is more than six feet deep it will maintain an unfrozen pool of water at the bottom. This pool of water being unfrozen all year, has a sufficient heat reservoir to keep the ground immediately below the lake unfrozen. This is zone in there. If the lake or river is more than a mile wide, and it has been in existence for a long time -- by that I mean in the many thousands of years -- there will be no permafrost beneath it, even along the Arctic coast.

The slide shows schematically conditions for a coastal lake where the mean annual ground temperature is minus 8 Celsius, and the mean annual lake temperature is plus 2 Celsius, or 18 degrees Fahrenheit and plus 6 Fahrenheit. You see at the lake, which is 500 meters or 1,500 feet in diameter, from there to there is 1,500 feet, will have a thick unfrozen zone beneath it. Should the lake then be drained, the unprotected lake bottom will be exposed to cold air temperatures equivalent to the surrounding land and permafrost will commence to grow on the exposed

lake bottom. If it drains and we take a temperature of plus 2 and substitute a temperature of minus 8, that means that we initiate permafrost growth.

THE COMMISSIONER: Mark that slide an exhibit.

(SLIDE MARKED EXHIBIT #53)

A Pingos grow then because a lake becomes drained and a lake bottom freezes over. However, permafrost surrounding the lake must be thick. The lake bottom sediments must be of sands and not clays and drainage must be rapid;if the same size lake were to be drained in the same material but at Yellowknife, probably no pingo would be formed.

The growth of pingo serves to illustrate the important point that freezing conditions vary greatly from one permafrost area to another, even in similar soil types, and in order to understand the occurrence of ground ice we must try to reconstruct the past permafrost conditions under which the ground ice grew.

When permafrost grows downwards a combination of a certain freezing rate, soil characteristics and ground water conditions may result in the formation of ice lens both small and large. Such ice is referred to as segregated or lens ice. The ice lens shown here is exceptionally large and pure. The ice lens which is in blue is just about natural scale. Usually ice lenses are interpolated with soil, there can be every possible gradation between the soil with a few hairline ice lenses to massive ice with only a

few hairline soil laminae. Segregated ice grows when the freezing plain remains stationary and when water moves upwards through the soil drawn by capillarity like alcohol to the flame of a lamp wick. What happens is if we take away the ice lens , this material was there. The freezing plain has remained stationary there, water has moved upwards to the freezing plain, and formed at the freezing plain and formed the ice lens above the freezing plain. The ground is then uplifted by an amount approximately equal to the sum of all of the ice lenses which have grown. The ground will heave then that amount. Conversely, if the ground is eventually thawed, water equivalent to the sum of the ice lenses is released and subsidence results.

Under natural conditions, areas of thick segregated ice can usually be recognized by slumping along steep bluffs which border the sea, lakes, or rivers. Here, for example, is a large exposure of ground ice four miles south-west of Tuktoyaktuk. An ice wedge can be seen at the top. There is an ice wedge . Here is the segregated ice, and the section is slightly higher than this room, about 30 feet in height. Icy sections such as this can fall back very rapidly.

Where ground ice is exposed along an eroding bluff, the slump is constantly reactivated by erosion. At an inland site where this erosion does not occur, slumps have a lifetime of about five to about 20 years; but where a slump is activated by erosion, as long the coast, it goes back. This one has been going back since 1935.

Insofar as is known, most of the massive ice lies at depths greater than 20 feet, and the distribution decreases from south to north. This is a collation of known data from about 15,000 shot-holes for the Yukon coast and adjacent areas. for those holes which have encountered massive ice. We see the ice as in the previous slide peaks at a depth of about 40 to 50 feet. Then as we go south from the coast, down towards Norman Wells, insofar as we know the abundance of ice decreases from north to south. In general, massive ice tends by its very presence to create a positive relief feature, it is positive because the ice grows and heaves it up, and this, when associated with those slump scars, aids in its recognition.

In the Mackenzie Valley ice veins and lenses are particularly abundant in lake sediments, discussed earlier by Dr. Fyles. The ice in these lake sediments tends to occur in a distinctive 3-dimensional articulate pattern very much like the cement in a brickwork system, and Dr. Fyles showed a land slide on the left bank of the Mackenzie downstream towards Fort Simpson. There are a number of land slides which have occurred, or slumps in this ice ridge of lake clays,

Permafrost conditions in the Mackenzie Delta are quite unlike those of the rest of the Mackenzie Valley. About 5,000 years ago the Mackenzie Delta was a large estuary, 100 or more feet in depth and the estuary probably extended south to Arctic Red River. As the Mackenzie River discharged

sediment into the estuary it built the present Mackenzie Delta. The Mackenzie River is still building its delta upward and seaward. At times of flooding, as in 1961 and 1973, much of the delta was under water, perhaps 80 or 90% of the delta was under water, sediment is laid down then on the flood plain of the river.

As the majority of the larger lakes and channels in the delta do not freeze to the bottom in winter, permafrost in the delta is perforated with hundreds if not thousands of unfrozen and interconnected chimneys and conduits like the voids in sponge rubber. That is perma frost in the Mackenzie Delta is not continuous, but is just like voids in sponge rubber, it is here and it is not in the next adjoining place. So there will be no permafrost in general beneath large lakes like that, or beneath channels, but there will be perma frost below the land areas. Consequently, when channels shift and lakes become enfilled, permafrost is thawed at one site and it grows at another.

Permafrost in the delta is commonly less than 400 feet in thickness. I don't think there are any records of permafrost more than 400 feet in thickness in the delta; there could be in the southern part but to my knowledge not in the north. Whereas permafrost depths exceeding 1,000 feet up to 1,500 feet, perhaps more, occur in the higher terrain on either side, so there is quite a contrast between the delta and the adjacent terrain.

THE COMMISSIONER: Dr. McKay,

in the delta, at what depth do you on the average usually encounter permafrost?

A You're thinking of the bottom of permafrost or the top of permafrost?

Q The top.

A The top. In the areas underlain by trees like this, it would be of the order of a foot and a half to three feet, depending upon the micro deposits there. In the sandy areas or the point bars it could be as much as three feet, four feet even.

Q And then extending to a depth of up to 400 feet?

A That's right, sir. Down in here, this is not a big land area but it could go down maybe here to 350 feet, and it would cut down underneath like that.

THE COMMISSIONER: Thank you.

A Although permafrost in the Mackenzie Delta is going downwards in a substantial proportion of the land area, it is also going upwards through most of the same area and thus in two opposite directions at the same time. The upward growth results from flooding of the Delta and the accumulation of organic matter. This means that the active layer is thickened by the acretion of material (that is, sediment and organic material) so the permafrost surface will rise upwards by a like amount. This is an insight schematic diagram of permafrost over a long period of time, shall we say a thousand years. This is past. That is present. On the vertical scale there that is 300 feet, 200, 100 and zero. If we go back some time in the past to this position, we would have a lake, as the lake shows and the lake bottom is built above river level, permafrost starts to build downwards and this is the downward growth curve of permafrost.

At the same time sediment is being laid on the flood plain of the river and the flood plain is being built upwards, so that is the surface in here. So we have permafrost going upwards here and downwards at the bottom. As the upward permafrost surface rises it will incorporate within it, both the sediment and ice lenses at the bottom of the active layer, that is as more sediment is laid down, the permafrost surface rises. Therefore, if half the volume of the active layer is lens ice then an addition of five feet of sediment will

result in an upward rise of the ground surface by ten feet of which half is soil and half is ice.

Incidentally this is the ice-soil ratio for the upper ten feet in the Aklavik area and it was measured in 1954 and was one of the reasons of course why Aklavik was not as suitable a sight for the development of a northern town as Inuvik.

The slide shows an eroded river bank with a spruce tree near a ranger station in the Mackenzie Delta. The survey rod in the foreground is 4.5 feet long. When the spruce tree commenced growth the ground surface was below the bottom of the rod. As sedimentation proceeded the permafrost surface rose and the spruce tree was able to maintain growth by sending out adminitous roots into the rising active layer. That is, the tree started growth when the ground surface was down here. That is about six or eight inches in diameter. As the permafrost surface has been agraded upwards in response to sedimentation, the tree has sent out lateral roots.

Clearly, permafrost has agraded upwards a minimum of 4.5 feet in the lifetime of this spruce tree. Therefore, at sites like this, permafrost is growing both downwards and upwards and the resulting ground ice in a single vertical section will vary in both age and origin. The permafrost and ground ice of the Mackenzie Delta then result from present conditions which are quite distinct from the

past conditions when permafrost grew elsewhere in the western Arctic Coast. For example, no mass of icy sections are known to have formed in the Mackenzie Delta. In contrast to such growth in the older, in the nearby, higher areas.

Natural disturbances. In permafrost areas where the ice content is high, the melting of ground ice frequently results in a depression formed by subsidence. A lake which originates-- which occupies such a depression is known as a thermokarst lake. The term thermokarst is derived from thermal and karst, K.A.R.S.T. The term "karst" refers to a distinctive type of landform for a solution in limestone produces depressions, caves and so forth, and Dr. Fyles showed us Oval lake near Norman Wells, which he mentioned was formed by solution of limestone. This is a karst feature, thermokarst is not solution by limestone, but subsidence by the melting of ground ice to produce depressions.

In the Arctic a thermokarst feature is caused by the melting of ground ice. Thermokarst lakes are abundant in the Mackenzie Valley and western Arctic Coast. I would presume if a person were to make a count of them, they would number in the many, many thousands.

The slide shows a 1935 oblique air photo of the coast 15 miles southwest of Tuktoyaktuk. Lakes A and B are thermokarst lakes about five feet deep. The lake bases were created

by the melting of ground ice. The shoreline possessions in 1935, 1950 and 1971 are so marked. The '50 and '71 positions are from air photos. From 1935 to 1971 the coast retreated at an average rate of 30 to 40 feet a year for a total distance of 1,000 to 1,500 feet. The rapid coastal retreat has resulted solely because the upper 15 feet of the ground is ice rich. Where the coast is only pore ice, as at the top right hand corner, coastal retreats since 1935 is hardly 50 feet. There is a contrast of about 50 feet on the top to a 1,000; 1,500 feet since 1935.

The next slide will show the coast for 1971. Please note first that in 1935 lakes A and B were, well inland. This slide shows the coast as it was in 1971, which is there, in 1974 the coast was up in there. Note that lakes A and B have now drained. The arrows in lake B point to three pingos have grown up since 1950. Permafrost is about 1,500 feet deep beneath the land areas, that is beneath these areas, an estimate of permafrost is of the order of 1,500 feet, therefore, it is obvious that at the 1935 seacoast position, which was down in here, permafrost about 1,500 feet thick is now covered by the sea and there is off shore permafrost caused by coastal retreat.

We should not get the false impression that this example is typical of the rate of coastal retreat, but it is a well documented case, selected to illustrate a common method of how off shore permafrost can originate.

In many areas surface disturbances to the active layer, whether by removal of vegetation, burning or heavy rainfall can cause thermokarst subsidence and thermal erosion. In mid August 1968 forest and tundra fires burned extensive areas in the lower Mackenzie Valley. Fires came quite near to Inuvik. Here is a burnt area two miles from Inuvik. It is between Inuvik and the airport on the north side of the road. The stakes there were driven down to the frost table a few hours after the firs had burned the site in 1968. The original vegetation cover of mosses, lichens, etc, has burnt off, but the fire swept by so quickly that the ground beneath never warmed up.

This photograph was taken in 1969 and vegetation was already becoming re-established and we can see that fireweed is coming up.

The next slide is taken from the same spot in 1972 and for identification we could pick out that tree. This is taken in 1972, two years later. Note the lush three foot vegetation cover which has replaced the original ground vegetation mat.

Now, let us compare the effectiveness of the two vegetation types, that is the original and the replaced vegetation, in controlling thaw depths. This slide shows the thickness of the active layer under the original vegetation cover at the time of that 1968 fire and the subsequent

changes until last summer in 1974. The ground surface is at the top, one foot, two feet, three feet, 68, 70, 72, 74. In 1968 the depth of the active layer was 1.6 feet. In '69 when the first photograph was taken, in there about 2-1/2, '70, '71, '72 when the second photograph was taken, about 3.3 feet.

We see that the active layer thickness continued to increase every year from 1968 to 1973, a period of five years after the fire. As there was very little change between 1973 and 1974 we can infer that the active layer is now stablized in response to the present vegetation cover. Although the rapid re-establishment of vegetation can prevent or minimize surface erosion, the active layer thickness obviously can continue to increase. The long lag effect which was five years resulted from the high ice content soil at the top of permafrost. It takes a long time for ice to thaw at depth. Or if we put it another way, that if this sight had been in sand, it would become stabilized probably within the first year.

It may be instructive to speculate on future changes to the active layer. Most likely, in a few years, perhaps beginning even this summer, 1975, the active layer will begin to thin and the upper permafrost surface will rise. The chances are this curve will begin to rise. As the upper permafrost surface rises, the segregated ice at the very bottom of the active layer will

become incorporated into the top of permafrost. The ground surface will then rise by an amount equal to the segregated ice incorporated into the rising permafrost surface. This is in direct parallel to sedimentation in the Mackenzie Delta.

A ground surface rise of a foot or more is quite probable. This type of response where the active layer is first thickened and then thinned, has been going on for thousands of years and that is the basic reason why the upper part of permafrost is often so ice rich.

The thermal explanation for a thickening of the active layer is as follows. When the vegetation cover is destroyed, as by a fire, the bare ground gets hotter in summer than it did beneath the pre-existing vegetation cover. We know very well that if we take grass from the lawn and measure the ground temperature and remove the grass, have bare soil, the bare soil will become warmer. What happens then is that this was the maximum summer temperature under the original vegetation;by removal of the original vegetation, the maximum summer temperature is higher, this shifts this curve from there to there, by shifting it the active layer is thickened. This then shifts the mean angle of temperature by that amount. The essence is that the winter temperature can remain the same, but if the summer temperature increases, the depth of thaw then will increase and there will be a shift in the mean annual temperature.

The increase in thickness of the active layer can be estimated fairly accurately from data on soil type and the time lag from the ice content at the top of permafrost. Off-shore permafrost. Permafrost occurs not only in land areas but probably over large off-shore areas of the Beaufort Sea. Some of the off-shore permafrost is merely land permafrost which has been inundated as the shoreline has been eroded back as we saw earlier in the example of coastal retreat in the section south-west of Tuk where we have had 1,000 feet of erosion since 1935, and we now have off-shore permafrost

1,000 feet off-shore.

When glaciers covered large land areas, world wide sea level was lower; and when glaciers melted and water was returned to the sea, world wide sea level rose. The world wide sea level changes are shown diagramatically in these slides, that is here we are in the present, 20,000, 40,000, 60,000, 80,000, 100,000 years ago. Here is present sea level, a depth of minus 100, minus 200, minus 300, and minus 400 feet. So this curve represents the approximate sea level curve going back in time.

For example, a site now 50 feet below sea level along the horizontal line would have been dry land approximately 60,000 years ago. There, it's just above, probably near the shoreline. About 8,000 years ago the site would have been flooded by a rise of the sea, and Dr. Fyles gave us data on the retreat of glaciers in the coastal area. So that that site would have remained as dry land from about there to about there, a period of about 50,000 years. In the Beaufort Sea area, long exposure of the land would have resulted in the growth of permafrost. Rough computations show that it could have grown to a depth of perhaps 500 to 1,000 feet or more, if there was no permafrost to start with.

However, the sea level rose and the land was covered by cold sea water. As Arctic sea water may have a temperature of minus 1 Celsius or lower, because of its salinity obviously it does not freeze at zero and it can be at a temperature below

zero, a marine transgression of such cold sea water will still perserve permafrost because it cannot melt at the top. The only way it can melt is at the bottom, and it would take at least 20,000 years for thick permafrost of 1,000 feet to melt upwards from the bottom.

Several years ago permafrost was recountedin somedrill-holes put in by industry in the southern Beaufort Sea. Each dot is one such site. For location then there is Inuvik, and this is the Yukon-Alaskan border. The next slide --

THE COMMISSIONER: Excuse me, Dr. McKay. Did you say that permafrost was encountered at each of those sites?

A Yes sir. The next slide will show ice samples brought up from the depth of 30 feet below sea bottom where the water depth was 40 feet. That is from this site off the north end of Richards Island. Here are ice samples from permafrost which grew,presumably when the area was dry land, and from here to here is one inch, so we see that those samples are slightly over an inch in diameter and there is very little doubt but that in the southern Beaufort Sea there is permafrost under the sea floor of presumably identical in most characteristics to permafrost under the land. This is surmised but it seems to be a fairly reasonable one.

Q And that would be so with respect to the depth at which you would encounter it, at the top and the bottom?

A Those wouldn't, sir.

But in the case of the coastal retreat at Tuktoyaktuk the sea water there is Mackenzie River water coming in off Tuk, and the mean annual temperature of the Mackenzie River water is above freezing, so what will presumably happen at that site -- and we have done some studies -- is that the upper permafrost surface will thaw downwards because of the warm Mackenzie water, it will go down fairly rapidly, the bottom will go up very slowly, the maximum rate is about an inch a year, it cannot exceed that. So that in the Kugmallit Bay area, permafrost is down maybe 50 or 100 or more feet in depth. But if we get westward towards Herschel Island, where we are under the influence of marine water, then presumably permafrost is close to the surface but there's a complicating factor that the pore water in the sediments can be saline so that it may not have the consistency of hard frozen ground, but definitionally it is permafrost.

Q I see, thank you.

A Climatic change. Superimposed upon the ever-changing physical landscape there have been major climatic fluctuations. As permafrost is climatically induced the distribution of permafrost has likewise fluctuated in response to climatic change. There is abundant climatic evidence from long-term air temperature data to show that temperatures in the northern hemisphere warmed from about 1850 to 1950, with a subsequent cooling trend from roughly about 1950. As the ground surface gradually warmed, from about 1850 to 1950, the response to the rise in air temperature was propogated downwards into the ground. The record

since 1850 is now preserved in the temperature of the drill holes. This slide shows temperatures measured by the United States geological survey for Point Barrow, Alaska; similar data is available for Cape Simpson and Cape Thompson. The 1950 curve is shown by the red line. The 1960 curve by the green line. You have then, down in here, depth in feet, 500 feet, 1000 feet, across the top temperatures zero or 32, minus 2, minus 4, minus 6, minus 8, minus 10, minus 12. The 1950 curve for Barrow is this curve in there. It goes along there from minus 8, follows this blue line and it straightens out and goes down and there is the bottom of permafrost at about 1,300 feet.

The 1960 curve is shown by the green line which is this line in here, it moved from 1950 to that position, a temperature of minus 9, it moved there and then that is the curve that goes does there.

If we had the 1970 curve, which we do not have, it tends, I believe, off in there, but I am not sure.

The interpretation is as follows. The longterm average temperature as measured over thousands of years is shown by these straight lines. This is the long-term temperature in the area, and projected up, it hits a temperature of minus 12. In 1850 the mean annual ground temperature is estimated at Barrow at about minus 12 degrees Centigrade or 10 degrees Fahrenheit. Then in 1850 which is a long-term average, this would be, it is estimated, the

temperature increase with depth. From 1850 to 1950 the ground surface warmed by four degrees, from minus 12 to minus 8. In other words, the ground surface warmed up like that, and it swung ' this temperature curve, it dragged it along with it, but since it takes time for temperature waves to propogate down, there is a lag with depth. So it warmed four degrees.

From 1950 to 1960 the ground cooled one degree, which is this. A similar warming and cooling trend is evident in the Mackenzie Valley. Although the temperature record is not as detailed as for Barrow, Alaska, the temperature records along the Yukon coast and the Mackenzie Delta show a temperature inversion with depth. It gets colder instead of getting warmer, as it should. At Norman Wells there are half a dozen curves which match this almost identically, like that. If you go up to Cornwallis Island you pick up the same thing. Melville Island, Ottawa, Winnipeg, Kapaskasing, Hurst and the Maritimes, a consistent trend, the trend is there, the actual amount varies very slightly.

Studies by Dr. A.S. Judge of the Department of Energy, Mines & Resources, show that the temperature at Fort Providence about 100 years ago was minus 2 Celsius, whereas now it is above zero, a temperature change of very roughly three degrees. That is Fort Providence had permafrost 100 years ago and it has since thawed. The estimate of Dr. Judge is that permafrost 100 years ago at Providence was probably of the order of 100 feet in thickness, and that has since

disappeared. Air temperature records for Fort Simpson show that the mean annual air temperature has decreased probably three degrees or more since 1950 , and a nearly equal drop in ground temperatures would be expected. This is a winter cooling effect, not a summer. It extends from Fort McPherson all the way down to Fort Smith; the Delta is a consistent trend.

Now, if we then look at that three degree cooling and look at our present ground temperatures, along the coast here they are minus 8 to minus 9. In 1850 the temperatures there were probably around minus 12. In 1850 Tuk would have had a temperature, let's say, of Sachs Harbour.

In 1850, down in here the temperatures in here, say Good Hope, would have a temperature of Inuvik, and Yellowknife would have had temperatures like that at Norman Wells. So that the change has been quite substantial.

If we then look at the distribution of permafrost as it might have been 100 years ago, I have drawn the 1850 limit down here as the southernmost limit that one would expect.

I think actually it probably was higher. But irrespective, I think we can say with fair confidence that 100 years ago permafrost was not where it is now, the boundary. 100 years ago the boundary of continuous permafrost was down in there. That is the normal case for the Mackenzie Valley, not the abnormal. Then these boundaries moved northward, that is the present estimated boundary of continuous permafrost, but that is probably slightly off.

In other words, the boundary of continuous permafrost moved northward; it meant that large areas of permafrost in here were thawed in the warming period from 1850 to 1950 and as a result of present trends permafrost is without any doubt, I think, growing in some areas in here. As a rough estimate, I would say 20 to 30 feet of permafrost has grown in some areas.

In the past 100 years then we can be reasonably confident although not certain, in stating that there have been major changes in the thickness of the active layer, in the rapidity of down-slope soil movement, in the development of permafrost lakes, in the formation of ice wedges, and in the disappearance and re-growth of permafrost. The effect of such changes would be large in the southern part of the Mackenzie Valley where permafrost is thin, and minimal in the north where permafrost is thick. That is the area most affected by climatic change would be down in here where permafrost is thin, up in the north I do not think it would have made a great deal of

difference. Consequently, permafrost is not static in the Mackenzie Valley because it responds to an ever-changing climate.

In conclusion, permafrost in the Mackenzie Valley and Northern Yukon is diverse in its age, origin, distribution and ice content. Along the Yukon coast some permafrost pre-dates the last glacier advance and it is upwards of 40,000 years old. By way of contrast, some permafrost has probably grown in the Southern Mackenzie Valley in the past 20 years as a result of recent climatic change. Some of the ice in permafrost is pore ice formed by the freezing of interspacial pore water. Some is segregated ice, accreted by the addition of ground water at the bottom of permafrost. Some is ice wedge ice derived from surface water.

Such ice types vary in vertical and horizontal distribution, and each type gives a different response to physical and thermal disturbance. Natural disturbances or changes such as thermal erosion, permafrost subsidence, ice ridge gulleying, lake drainage, slumping, fire, coastal erosion, marine inundation, and climatic change have been taking place for as long as permafrost has been in existence.

Natural disturbances are the surrogates for artificial disturbances and we have much to learn from them. In this overview of permafrost attention has been deliberately focused on ground ice and its problems. In doing so, we should also remember

that there are very extensive permafrost areas which have so little ice that the response to a change is essentially similar to the response of a non-permafrost area to the same change in Southern Canada.

THE COMMISSIONER: Thank you very much, Dr. McKay. We are in your debt.

(WITNESS ASIDE)

MR. SCOTT: Mr. Commissioner, could I suggest that we should adjourn now and come back at one o'clock?

THE COMMISSIONER: All right, we'll adjourn until one o'clock.

(PROCEEDINGS ADJOURNED AT 11:30 A.M.)

(PROCEEDINGS RESUMED AT 1 P.M.)

MR. SCOTT: Mr. Commissioner, at the beginning this morning Mr. Anthony made some requests of you,and I suspect of me, and I asked if I could consider them and respond. I've now had an opportunity of looking at a praece of what he said. He really asked two questions, as I understand it from his words:

(1) Whether Commission counsel could inform him and his colleagues that the Department of Environment witnesses who have relevant testimony would be made available to the Inquiry, and

(2) He asked you to instruct Commission counsel to communicate with the Minister of the Environment to determine that Department of Environment experts who have relevant evidence would be made available at government expense to present their evidence.

Now let me deal with the first question or the second question, is it possible for us to provide an assurance that Department of Environment experts who have relevant testimony to give will be available at government expense?

We have now, since this morning, obtained assurances from the Department of Indian Affairs & Northern Development that any expert witness in the Public Service of Canada who has relevant evidence to give to the Inquiry and who is called to testify will be available at government expense to present their evidence; and government expense, just so it is clear, means that travel and associated expenses will be paid

and the payment of the witnesses' salary will continue while of course they are engaged in giving evidence at the Inquiry. So I think that that assurance complies fully with the second request that my friend made.

The first request, can Commission counsel inform us that the Department of Environment witnesses who have relevant testimony will be made available to the Inquiry? I have considered that and in the course of considering it I have seen a press report which was in the "Globe & Mail" of February 28, 1975, and which, for the purposes of this answer, I assume to be accurate. In that press report the Minister of the Environment, Madam Sauvé was reported to have decided to put department experts at the disposal of the Inquiry and to open all doors on environmental information and expert knowledge held by the Department. As a result of that press report, which I assume to be correct, I propose today to communicate with the Minister of the Environment to accept that invitation on behalf of the Inquiry and to consider ways in which that information and knowledge can promptly be made available. At the same time and in the same way I intend to communicate with the Minister of Indian Affairs & Northern Development, and I hope that after that communication has gone forward I will be able to report in public to the Inquiry about its results shortly. I think that second question therefore is responded to in that way. I will make the enquiry requested and I will report to the Commission.

THE COMMISSIONER: So I take

it we can leave that matter there for the time being, Mr. Scott.

MR. ANTHONY: Mr. Commissioner, in view of the -- our involvement in this I would just like to briefly say that I welcome the comments of Commission Council in respect to the actions to be taken and I would urge the Government to respond favourably to these directives and I would hope that in carrying out of the action that has started today, that we will be able to co-operate with the government and with this Commission in ensuring that these issues are brought before the Inquiry and I look with confidence in the rapid resolution of this matter in order that this hearing can proceed in the prompt fashion that we all desire.

Thank you.

MR. SCOTT: Mr. Commissioner, the next overview witness is Professor Michael Church and his subject generally which he will introduce is an overview of hydrology in northern rivers.

Mr. Church.

MICHAEL ANTHONY CHURCH, sworn.

THE SECRETARY: Please state your full name.

A Michael Anthony Church.

DIRECT EXAMINATION BY MR. SCOTT:

Q Professor Church, I understand that you are an assistant professor of geography at the University of British Columbia, is that correct?

A Yes, that is correct.

Q And can you tell the

Commission where your university training was taken and in what general subjects.

A Yes, my undergraduate training was at the University of Toronto in the subject of geography, particular attention to physical geography, and after that I did graduate studies at the University of British Columbia with specialization in geomorphology and I was particularly interested in the geomorphology of northern lands.

Q For my benefit if not for the benefit of anybody else, what is geomorphology?

A Geomorphology is the study of the form and processes that change the form of the surface of the earth. So it is the study of erosion, sedimentation, river activity, slope activity and the like.

Q Yes, well now, Professor Church, have you been engaged from time to time in any field work in this specialty?

A Yes, I have. I have spent a total of ten years in the study of geomorphology in northern Canada. I have spent eight seasons or parts thereof in Eastern Arctic studying glaciers, rivers and river sedimentation, in that part of the world and part or all of four seasons in the northwestern part of Canada and adjacent portions of Alaska engaged in similar pursuits.

Q Yes. Well now, I understand that in 1971 and 1972 you were engaged doing work for the Mackenzie Valley Pipeline Research

Company Limited. What sort of work was that?

A That was a reconnaissance of hydrology and river conditions along the route of a proposed oil pipeline from Prudhoe Bay to Edmonton, Alberta, which was routed via the Mackenzie Valley.

Q Yes, I see.

Well now, Professor Church, I would ask you to carry on as the other overview witnesses have. Please.

A Thank you.

THE COMMISSIONER: Just a moment, Mr. Church. Mr. Genest, if you or any other member of counsel has any difficulty hearing just move your chair over here.

MR. GENEST: These interventions of yours please me. The people behind me stop talking and I can hear.

THE COMMISSIONER: Mr. CHurch, just one question before you start. You said that you had been working with the Mackenzie Valley Research Company in connection with a proposed oil pipeline from Prudhoe bay to Edmonton. During what period of time was it that you were engaged in working with that company?

A I began this investigation in May of 1971 and my investigations for them were complete by September 1972. My findings were incorporated in two reports that were printed by the company and released to interested parties, including

Government parties, as part of their reconnaisance to inquire into the feasibility of such a line. I understand that that work has not gone any further and finished at that time.

THE COMMISSIONER: Thank you. Well, carry on in your own way.

A Thank you.

Well, Mr. Commissioner and ladies and gentlemen, I have been asked to discuss aspects of hydrology and rivers in Northwestern Canada. Running water on the land is important both as one of the major agencies that erodes and shapes the surface of the land and of course it is a vital material for the support of life.

In addition in the North, frozen water produces special and important seasonal and long term effects, some of which we heard about this morning when my collegue Professor McKay discussed some aspects of water under the surface. During my remarks I want to add to this by making some discussion about the effects of surface ice as well.

Can I have the slide projectors please.

The slide on the right. -- I would like to begin by indicating that the terrestial phase of the surface of the land of the so-called hydrological cycle which describes the movement of water at or near the earth's surface, can be simply characterised as on the right here by the division

of precipitation inputs and in this diagram the triangles indicate inputs and outputs of water and the square boxes indicate major storage points and the diamonds indicate points at which major divisions in the flow of water occur.

So here, precipitation is divided into two streams, one of which constitutes direct run off on the surface of the land when rainfall occurs on the surface for example and the other of which consists of water that percolates into the surface of the ground and remains in the soil as soil moisture or as ground water. Some of the moisture which percolates into the surface of the ground according to local climatic conditions may subsequently be evaporated directly from a moist soil surface or much more important, much of this moisture is taken up by plants and transpired in the course of plant activity.

Some of it may subsequently seep back to the surface in springs and join the direct runoff on the surface,where it passes via lakes, bogs and river channels,ultimately in runoff to the sea. So in sum, in that portion of the hydrological cycle in which we are interested, precipitation inputs find their way either to evaporation and transpiration or to runoff from the surface of the land and we will be particularly interested in the conditions of runoff.

Well, in Northern Canada, this simple picture of the hydrological cycle is somewhat modified by several features that are related to the

extreme thermal conditions including the ground thermal conditions which Drs. Fyles and McKay discussed this morning, so that processes leading to runoff are somewhat different and this modified diagram on this side illustrates some of these modifications.

First of all, important everywhere in Canada, is the possiblity that when precipitation falls, temperature conditions will be below freezing and so the precipitation will fall as snow and be passed into snow storage, thence to remain on the surface of the land until in the spring, local warming of the atmosphere produces snow melt when the melt water becomes available for movement further on through the hydrological cycle.

Some other important differences occur in the soil moisture term over here, the ground thermal climate will determine whether on a seasonal or as Dr. McKay described this morning, on a long term basis, moisture may remain in frozen form in the surface, or under the surface of the ground as ice. And again, down here standing water on the surface and water in river channels as well may seasonally be frozen at the surface so that ice cover forms on lakes and river channels and then in the following spring melt returns this water to the fluid form and it continues to move through the terrestial hydrological cycle.

So these major changes are related -- or these major complications are related to

the extreme thermal conditions that we find in northern Canada.

M.A. Church
In Chief

The most important of these effects, so far as short-term view of the hydrological cycle is concerned is the routing of precipitation to snow storage for much of the year. In Northern Canada it's 7 to 10 months' precipitation, depending on where one is and how long the winter and summer seasons are locally. 7 to 10 months/ precipitation input remains as snow in storage on the surface of the land and then it is all melted in a few weeks in the spring of the year. The hydrological effect of this is that 7 to 10 months' precipitation is re-distributed as if it had all occurred during that brief period of snow melt. So far as the movement of water on the surface of the land is concerned, it is as if all of that precipitation had appeared in a few weeks instead of over a period of seven months or more.

Most northern regions do experience a summer maximum of precipitation so that during this 7 or 8 or 9-month period of the year about one-half of the total annual precipitation falls, so about one-half of the total annual precipitation is effectively stored and then released or run off from the surface during a short period in spring. On this map, which summarizes the annual precipitation in Northern Canada, the dotted contours indicate the proportion that falls as snow. In the Mackenzie region, which is the study of main interest, between 40 and about 50%, 45 to 50%, more in the mountains of the total annual precipitation occurs as snow.

So the effect of snow storage

in re-distributing precipitation input is the single most important feature of the modified hydrological cycle in the north. The hydrological significance of summer rainfall, the other half of the precipitation, is largely tied up in the intensity with which individual rainstorms may occur. Relatively warm air masses in summer may carry a far larger amount of water vapor than cold air masses of winter, so that when meteorological conditions produce precipitation, it's possible that far larger, far more intense precipitation may occur than usually occurs in the winter.

One such intense summer rainstorm was one that occurred in the Upper Keele and Arctic Red River regions of the Mackenzie Mountains west of Mackenzie River, on July 20 and 21, 1970. This storm has been studied reasonably well. The slide gives a meteorologist's estimate of the total precipitation that occurred during the storm, and near the centre of the storm over a period of -- I believe the summarization is for the period, July 18 to July 21 -- during 20 and 21 July most precipitation fell, and the total was five inches or greater precipitation in this central region, and less as you move farther away.

I should like to emphasize that the relative lack of observing stations in the region, major climatological stations are indicated and they all fall nicely around the central region of the storm, I'm afraid, make it rather difficult to be sure of this data. So this can at best be seen as

approximation of conditions that occurred.

By comparison with data of other storms experienced at the Weather Stations in the region, it was decided that the return period for a storm of this size -- that is to say the mean time between recurrences of a storm of this intensity and magnitude -- should be of order, 10 to 15 years. This particular storm caused extensive flood damage on several rivers, particularly upper reaches of the Arctic Red and Mountain and Rivers which -- the Keele River down here -- which drain to the Mackenzie, and an examination of damaged trees along the upper reaches of these river courses led to the hydrological estimate that the flood produced by this storm only recurred once every 100 years or so, along these rivers.

Now there's quite a discrepancy between this estimate and the estimate of the recurrence for a storm of this sort, based on the meteorlogical studies. This might partly reflect antecedent conditions. It may be that before this particular storm arrived there was already quite a lot of water stored on these water sheds, in the soil, in ponds, and so most of the precipitation ran off, whereas on other occasions a good deal of precipitation would remain on the water sheds in storage. But I think mainly this discrepancy is the result of the geographic localization of the extreme effect of this storm within a fairly small region -- but in absolute terms it is not small but it's fairly small by compari-

son with the density of the regular weather observation network, and unfortunately, it's particularly centred in this mountain region where there aren't many regular observing stations.

So consequently, though meteorlogical storms of this scale may recur in Northwestern Canada with a frequency of a decade or so, in each case the effects, the storm centre will perhaps be located in a somewhat different geographic place and so the most extreme effects of such a storm will occur in a slightly different place than they occurred the last time, and consequently only much more rarely are the most extreme effects visited at one particular place.

The lesson of this, and the reason why I've described this event in some detail, is that in hydrological work we must rely to a great extent on available historical records of the sequence of weather, of the sequences of run-off in the various rivers, and the history of this storm and the results of its analysis indicate that our observing networks of Weather Stations -- and the same is true of our Stream Gauging Stations in the north -- is sparse, too sparse to be able to measure the full geographical variability of events that occur. So we must be very careful in interpreting the range of conditions that can occur in Northwestern Canada from available records, for we may not be seeing anything like the full range of events that may occur, because of the sparse nature of the measurement network.

The presence of permanently frozen ground in the north, discussed by Dr. McKay this morning, restricts exchanges between surface water and sub-permafrost ground water, so that there is a lot of standing water occurs on the surface as a frequent result of this. As Dr. Fyles pointed out, though much of the north constitutes climatic desert, by classical standards, total precipitation is quite light through much of the north, reduced evaporation in the cold climate in the north and the restriction of most water circulation to the near surface. The possibility of deep percolation into the ground is prevented by the presence of frost, so that only a few restricted sites, such as on sandy ridges, do conditions of physiological drought frequently occur, and that most places on the surface in the north, there's an abundance of water during the summer season of the year when it's important for the growth of vegetation and so on.

The chief contributions to run-off in the rivers then come from seasonal snow melt and seasonal rainfall by direct surface flow on the surface -- that's down this line or this line -- or as the result of flow through the shallow soil and then back to the main line as delayed run-off, but not as the result of deep percolation and then resurgences at springs, deep springs. So run-off in much of the north can be analyzed as a surface flow and soil flow phenonenon, and deep ground water circulation need not be considered as important.

In such circumstances, winter flow in streams often becomes very small and most small streams have no winter flow at all. On the Arctic slope, this may be true even of sizeable drainage basins for in the winter the active layer freezes seasonally, water within it is frozen, and no water movement occurs and there is no seepage from deep sub-permafrost sources.

This slide plots minimum monthly discharges during the winter, normalized with respect to drainage area against mean January temperature.

Those stations where there is no permafrost are generally in the upper right-hand portion of the diagram, indicating that there is considerable winter flows experienced. This is because ground water continues to feed small amounts of water into the river channel which flow off/ year round. In regions of discontinuous permafrost, winter flows are somewhat reduced, and in areas of continuous perma frost we have very low or zero winter flows on the whole.

The data base for northern run-off is shown on this diagram on the left. It's not a good data base, particularly when it's realized that many of the stations are on the main stem of Mackenzie River itself. The Mackenzie River is a very large river, whose run-off comes from extremely large area, and so the river effectively integrates the variable effects of run-off from many places. At one time a storm in this region or some storm in this region may introduce considerable water into the system; at another time a storm centred up here, perhaps might introduce considerable water into the system, but usually not from both places at the same time. The net result is that in one way and another the river maintains a fairly equitable flow, through all this local variability in run-off supply.

So once again, much of the regionally variable character of the hydrology of Northwestern Canada is lost from the available records. Before continuing, I'd like to point out that basic Stream-Gauging Stations are indicated by the small dots

and the larger ones. Those stations where in addition sediment transport observations are made, have orange rings around them, and those stations, primarily the same ones again, where winter ice thickness observations were made of the green ring outside that.

More unfortunate still from the point of view of being able to study the character of hydrology in the north is the fact that a number of stations with more than five or ten years' worth of records are even fewer than the number of stations shown here, and they are virtually all on the main stem of Mackenzie River or a few lake controlled tributaries. The slide on the right shows the number of stations with useful long-term records.

We have very little information on a long-term basis from tributaries on either side of Mackenzie River itself. Beyond research results of short duration, there are almost no records from small water sheds, and as I will try to show later on, it's very often in small local areas, that most extreme effects of particular hydrology events are visited.

The pattern of run-off in the rivers can be categorized broadly on a regional basis. Mr. Commissioner, some of the data on the slides I'm about to show you come from rivers that are not within the region of main interest. They are rivers, however, all within Northern North America, and in each case I believe the effects to be comparable with those you can expect from rivers within the area of interest. The reason for my choice is that to illustrate some of these

hydrological regimes there is simply no record available within the region of interest.

These two graphs show on a seasonal basis what I call Arctic Nival Regime. Nival refers to the dominance of the run-off regime by snow-melt events in the spring, "nival" referring to snow-melt. In these areas which are areas of continuous permafrost there is little possibility for winter run-off and so these streams are winter-dry, consequently these graphs are restricted to the period, May to October.

The spring snow-melt flood is apt to be the most severe one in rivers of this type for the generally light peak intensities and low volumes of summer rainfall are usual in the Arctic regions where this regime type is found, in comparison with the sub-Arctic, which we will look at in a minute.

In very small water sheds, locally severe precipitation may occur in the summer and floods in small water sheds may approach or exceed in magnitude the effect of the snow melt flood. So on this small river which actually is on Devon Island in the Canadian Artic Archipelago, some events in the summer, the result of rainfall, appear quite important in the run-off record; whereas in this large river, the Colville River which drains part of the Alaskan north slope and has a regime not much different from that which we would expect on Firth River, for example, on the Yukon north slope, the spring snow-melt event is easily the most important.

An interesting feature of this particular run-off regime is that in the spring run-off usually commences over ice lying in the channel bed from the previous autumn. Run-off must break through snow drifts in the channel along the way.

In the sub-Arctic, generally areas within the tree line, we have a sub-Arctic Nival Regime. This is characterized by an important snow-melt flood in the spring, here illustrated on White Sand Creek, an east bank tributary of the Mackenzie River. That photo was taken on May 10, 1973. Then there are generally low levels of flow throughout the summer period thereafter, but punctuated by periodic rainstorm floods, and this is evident particularly on this graph for Arctic Red River near Martin House. Please note that this graph is based on a different year length than this one here, January-December; in this case, January through December, so run-off occurs, peak run-off occurs at the proper time, despite the changed axis.

The rainstorm floods of summer mav be more severe than the spring freshet on these rivers, and we can see this on the Arctic Red case, in this case the gauge was not operative part of the spring snow-melt flood, but we can see that fairly major summer rainstorm floods do occur. I can refer you again to the July 20-21 storm that we looked at a while ago, which was the most extreme hydrological event that some of the rivers in this region, including Arctic Red River, have experienced in many, many years.

That was not associated with snow melt.

These two slides further illustrate the importance of summer floods. They are two views of a small creek opposite Rigley where about two inches of rain occurred locally in 12 hours, in late July of 1974. This view, showing the usual summer conditions of the creek, is taken from the building that's shown in the view on the right.

In the sub-Arctic Nival Regime, small rivers are winter dry but large ones may continue to flow under ice cover year-around. Much of the base flow is derived from unfrozen gravel along the channel, although deep springs do occur in the mountains, in particular there are thermal springs at several points in the Mackenzie Mountains and British Mountains of the Northern Yukon. This sub-Arctic Nival Regime type is particularly characteristic as well of northward flowing rivers, such as Keele River, Arctic Red River, whose headwaters may lie in discontinuous permafrost country to the south, and where there is a possibility for continued winter re-charge of the river from deep ground water occurs.

I'll ask you to ignore this top graph. I'm afraid these slides are doing double duty and they've been used before in another context.

I wish to draw attention now to what I call the Muskeg Regime which is important in Northwestern Canada, as Dr. Fyles points out, there are large areas of peat and muskeg landscape. This regime type is also characteristic of lake controlled

drainage basins, in fact Kakisa River is lake controlled as well as having a good deal of muskeg in its basin.

The view on the right is taken looking toward Roche-qui-Trempe-a-l'Eau on Mackenzie River from the north end of the Camsell Range, and shows typical forest and muskeg at low level along the Mackenzie Valley. Muskeg is intimately associated with poor drainage. Because of the large water-retaining capacity of the vegetation, as well of the direct impediment of a run-off that is presented that Dr. Fyles illustrated, flood peaks are strongly attenuated in muskeg dominated water sheds.

Inthe Arctic, grassy or heathy tundra, which is often hummocked as well, as a result of frost heave in the active layer, similarly has the capacity to hold a great deal of water and to therefore strongly attenuate flood peaks of run-off so that much less abrupt run-off peaks occur in rivers of this type than is common in the two regime types that we've looked at earlier.

For the small watershed at Ogotoruk Creek, which is actually in Arctic Alaska, more peaked floods do occur including one major rain storm flood shown here, but again, as I will demonstrate in a moment, the effect is considerably damped over other small watersheds of the type.

Lowland tundra with much standing water on the surface, behaves similarly as well, as a great deal of water can be stored on these ponds and standing water places after precipitation events. It does not run off immediately.

On these Arctic tundra water sheds, if the sod mat is dry before a summer rain storm occurs, a great deal of moisture can be stored in this erstwhile dry sod mass or in hollows and ponds on the surface, so that little runoff will occur. On the other hand, if wet conditions precede a storm, then there may not be nearly so much storage available and then there may be a much more peaked run off, as probably occurred in this particular case, for example, it may have been a continually damp period, in addition this is probably a pretty major storm.

Because of the importance then of the antecedent condition, there is very variable response of the small Arctic watersheds to reasonably small storms. This is indicated here, where the rainfall is plotted against the peak discharge observed and the data is from Ogotoruk Creek. For small storms a very variable response which depends on how wet the watershed is before precipitation input

occurs. For large storms of course, which always exceeds the storage capacity of the watershed then a fairly predictable response begins to be ascertained.

It is interesting to compare the response of these tundra, heath dominated watersheds with the response from barren watersheds, terrain of this type which is common in the Mackenzie Mountains to the west of the Mackenzie River, for example. And this compares the storm response of Ogotoruk Creek with the response of Twisty Creek, a small watershed in the Mackenzie Mountains and superficially the responses look similar except that for Ogotoruk Creek the time axis for the storm runoff in the river is multiplied by ten over that of Twisty Creek. This means then that the rise of the flood wave and the decline are about ten times longer for Ogotoruk Creek than for a comparable condition at Twisty Creek on the barren surface in the mountains. On this barren surface there is not much place for moisture to be soaked up and retained on the watershed, realizing the substrata is frozen at a shallow depth as well, so not even the soil provides much room.

It follows that for equal precipitation inputs the flood peak will be much more severe on a watershed of Twisty Creek site, -- or Twisty Creek characteristic, I am sorry. On this diagram, this characteristic has been disguised since the runoff is normalized by dividing by the peak discharge for the watershed in each case, so we have a normalized scale of zero to one here.

The occurance of ground water in permafrost regions is something that I would like to say a few words about. It is not essentially different from its occurance in general elsewhere. However there are several important modifications that result from the presence of frozen ground.

First of all, obviously in frozen areas, water is rendered immobile as ice, so it does not move. Permafrost is effectively an impermeable barrier to water movement, so if there is permafrost it increases the number of barriers to ground water movement in the active layer. For example, in particular, ground water movemnets are often constrained to the corresponding surface water catchments in permafrost areas, since surface drainage divides usually correspond with highpoints on the frost table under the surface.

This is different from conditions in the south where very frequently ground water drainage does not correspond with surface drainage catchments, so that in the North in fact, hydrological analysis is sometimes simplified by this fact. We can treat each individual watershed as essentially its own unit which receives precipitation and ultimately either evaporates it or sees it pass out through the stream channel that drains it.

In the south we cannot always -- we frequently cannot assume this.

As well, permafrost can alter water tables, that is the level below which standing

column occurs in the ground from normal configurations and this may complicate the analysis of soil and ground water. In areas with permafrost this becomes a particularly complicated problem in the areas of discontinuous permafrost. Where there is frost under the surface, you may have a high water table perched on top of that frost, where there is not frost, no permanently frozen ground under the surface and you may have effective drainage so that the underground water level is a much greater depth.

The occurance of ground water is associated with riverflow in two ways. First, it leads to the possibility of continued flow through the winter as I have indicated in discussing subarctic nival runoff regimes, and often this flow may be below the channel bed through permeable gravels, where the river bed remains unfrozen. Where springs or seepages occur to the surface, massive accretions of surface ice known as icings, one of which was illustrated by Dr. Fyles, can develop during the winter and I want to discuss icings later for they have some important consequences for the stability of river channels.

Turning now to look at the rivers themselves, that carry the runoff we have been discussing, the character of a river is determined by several features, amongst which the following are particularly important.

First of all, the imposed run off. The river channel must be capable of passing

the water that arrives in the channel.

Secondly, the sediment load that comes with this water from upstream is important in determining the character of the channel. Hence, geology, including the erodibility of bedrock and unconsolidated materials in the upstream watershed become important for these will determine the condition of sediment supply.

Third, the particular bed and bank materials through which the river is flowing are important for these will help determine the particular configuration and stability of the river channel.

Fourth, the gradient down which the river flows is an important factor in determining the character of the river channel. This gradient may be imposed by physiography or geology, as when the river flows on bedrock that it cannot easily erode, or the slope may be determined by the river itself when it flows in its own deposits, its own deposited sediment which we will call alluvium.

Since each of these factors can change along the course of a river, bed and bank materials may change, discharge commonly increases downstream of course as tributary channels join a main channel and the sediment delivered to the channel changes accordingly. We can expect the character of a river channel to change as you proceed downstream along it. It is therefore prudent to characterise individual lengths of a river channel or reaches

rather than to try and characterise or classify entire rivers per se.

I will define a reach as a length of river channel within which each of the conditions that I have just mentioned remains substantially unchanged, so discharge, sediment load, bed and bank materials, and the gradient of the river remains substantially unchanged and in these circumstances we can expect the channel to have the same morphological character, the same features along this length, clearly my conditions mean that a reach will be restricted to a length say, between important tributary junctions, for at that point discharge will change as the tributary flow is added.

What I am going to do now is indicate to you several types of reaches that are commonly encountered in rivers in Northwestern Canada. Now, this is not meant to be an exhaustive classification, nor do I mean to indicate that peculiarities of particular reaches may not be very important, but in the absence of much specific data about northern rivers, I think that this is a useful way of generalizing a lot of important pieces of information about the way that rivers behave.

In the diagrams, the first of which is on the left here, I would like in addition to point out that the blue colour in the channel bed, these are cross section diagrams of river channels, and the blue colour is intended to indicate winter ice

conditions that are characteristic of these channel types that I will discuss, whereas the red dotted lines are intended to indicate characteristic summer frost tables under these rivers, so I am trying to indicate frost conditions around these river channels at the same time.

Now this is inconsistent in the sense that I am looking at summer frost conditions and winter ice conditions, but it conveys useful information on the one diagram. I have not commonly shown water levels within these channel diagrams.

The first river type that we can look at, using the character of bed and bank materials as the primary criteria for classification, and then river pattern as a secondary criterion, for these are the two things about a river that we can see right away when we go to visit it. We have to wait and gather records to find out about the runoff regime or the sediment transport, but we can see these things right away so they are useful basis for the classification.

First of all, we may look at large gravel rivers, rivers flowing in gravel, cobble, stoney channels.

The first type of pattern we'll look at is the so-called braided pattern, which is illustrated on the right by a reach on Mountain River just above the consolance with Gayna River. In this river type we see many channels, many individual channel segments which occur within a wide channel zone. So here is a channel zone, and within it many individual channels, and these channels are wide and shallow, characteristically wide and quite shallow, and they're subject to rapid shifting. They are generally unstable. We can see that in general the bars between these channels have no vegetation on them, indicating in a high flood flow they may be entirely drowned and it indicates the channels themselves rapidly erode laterally, deposit on another side and move back and forth individually. In fact the entire channel zone is also liable to shift quite abruptly. Such channels are associated with heavy sediment loads, and in particular heavy loads of coarse material that moves along the bed of the channel -- sand, gravel, and in high flood, cobbles. Often much of this material may be deposited within the reach so that the river bed is raised and aggradation commonly occurs along river channels of this type.

In the Arctic these channels are usually winter dry and so permafrost can occur at fairly shallow depths beneath such a channel. The second type, so-called braided anastomosing is illustrated on the right and the ten-gallon term, "anastomosing" is taken to refer to rivers with several channels but

within which the islands between the individual channels are permanent or more or less permanent. What I mean by "permanent" is that they persist for long enough for mature vegetation to develop on them. In nature, of course, if you take a long enough view of things, nothing is permanent, but as opposed to the rapidly developed and destroyed channel bars of the braiding type, these channel islands in an anastomising river last a long time. Now there may also be sections where the river braids, and there are channel bars come and go quite quickly, so this is a hybrid type channel. Some of the islands persist; some of them come and go. These channels usually have somewhat better defined individual channel ways than the braided type and they're more stable than the braided channels that I've referred to. Such rivers carry lesser sediment load than do braiding channels, and often they are not aggrading. In fact, a braided river that has been aggraded and then for some reason sediment supply is reduced may often change its character over a period of time so it becomes an anastomosing river. So we are seeing the results of reduced sediment supply in a river of this type.

The illustration in fact is a reach on the Porcupine River tributary, it's actually on the Alaska side of the border but similar rivers are common on the Canadian side as well. That was a good illustration that I happened to have.

A third type is a Gravel River that flows in a single channel which is well-defined.

These rivers, illustrated by this cross-section type, are usually stable. They may actually be degrading, which is to say the characteristic of the river is picking up sediment and moving it out of the reach so that the bottom of the river channel is being lowered. Very often after this has occurred for a while, the floor of the channel becomes covered with a layer of large cobbles that the river cannot now move. These cobbles might have appeared in the river section at an earlier time when the river was more powerful, more water running down it perhaps and was capable of moving larger material, or the material might have been put there by other agencies, perhaps the river had been eroding in glacial till when it encountered large cobbles in the glacial till.

Such a deposit of large cobbles on a stream bed is called a lag deposit, since it's material that is left behind when finer material is eroded away, and once the floor of the river is covered by these things, it usually becomes stable under normal alluvial forces. The illustration on the right is a reach on Babbage River on the Yukon north slope. In the sub-Arctic we have rivers like Willow Lake River, which is a similar well-defined single channel in gravel.

Moving along to the second major type, in the Arctic we find some large rivers that characteristically have sand beds and high silt banks. Looking first at the anastomosing case, which is illustrated by Arctic Red River near Martin House,

on the right, the effect of the silt banks is to restrict the river to a narrower, deeper channel than is the case in sand and gravel. Silt is cohesive, it has some resistance to erosion, and so rather than eroding rapidly to a wide shallow channel, the river is restricted within silt banks and takes on a deeper, narrow section. Since the banks erode reasonably slowly, the channels remain well-defined and they shift only slowly. The sand bed of these rivers may be subject to quite rapid scour and fill during floods, however, usually greater depths of scour and fill than you may find on the gravel rivers we've been looking at.

These rivers carry a relatively high load of suspended sediment, fine material that is carried within the flow itself and not dragged along the bed.

THE COMMISSIONER: Excuse me, Mr. Church.

A Yes?

Q To go back, you introduced the subject of scour there for a moment.

A Yes.

Q Do you mean ice scour?

A No, I mean scour due to the fact that as a floodway comes down the river channel, water levels rise, velocities increase, and so greater sheering forces are brought to bear on the bed and consequently erosion of the sand on the bed occurs, material is entrained in the flow and taken away. I will deal with this subject again in a few minutes

and I will discuss ice scour at some length later on.

In rivers of this type when the suspended sediment load is -- or a portion of it is often deposited over bank, outside the main river channel, and when the river channel floods the common conception, I think, that most of us have of a river, is of a river of this sort, it sits within its banks and is normally well-behaved, but occasionally large floods occur, the river gets outside its bank and deposits a lot of silt all over the countryside and this is the sort of thing we read about in the newspapers very frequently. The reason the sediment can get outside the banks in large measures is because it's carried in suspension on the load, so when flow outside the banks in the flood, sediment goes with it, and then is deposited when the waters slow down outside the banks.

So consequently these floods and the associated deposition contribute to the building up of the river's flood plain and the heightening of the banks. Large rivers of this type usually contain water year-around, or they are usually deeper than the seasonal depth to which ice-covered grows on the river surface and so there will be flow in the winter under the ice cover. Rivers of this type may be aggrading or they mav be stable, or they may even be slowly degrading.

Single thread channels of this type, such as is illustrated in section here, are similar to the anastomosing channel I've just described, except

that they're more often stable than degrading, and they're not aggrading at all. Rivers of this type with single channel, usually meander more or less regularly, and the meander shifts showly across the river flood plain. Since there is water in the channel year-around, and the temperature of the water then must be above the freezing point, it follows that the temperature of the bed below the river channel will remain above the freezing point as well and so under rivers of this type we do not usually find frost at shallow depths below the bed. So in permafrost a cross-table of permafrost will drop sharply away under the banks of the river. Now if the river is sufficiently small and the permafrost is sufficiently thick then we may find permafrost at some depth. These lines may join.

If in fact the river is very large, permafrost is reasonably thin, in fact there may be no frost at all under the channel zone at any depth.

I'd like to indicate several special channel types that occur in Northwestern Canada. The first one is rather unusual, and they are what I call estuarian channels, for a reason that I will tell you now.

Along the Mackenzie River the tributaries entering the main river usually are anomalously wide and shallow at and near their mouths, at or near Mackenzie River itself. This feature is common in channels that are frequently in back-water,

channels that are frequently flooded from down-stream. Notably tidal estuary channels where every 24 hours or every 12 hours, perhaps, there's a twice-daily tide, the tide rises and floods back into the river channel. Then the channel becomes very wide and shallow.

THE COMMISSIONER: These are flooded by the main stem, is that right?

A Yes, in this case we're not dealing with a tide but we're dealing with the important annual flood on the main stem of the river. So a back-water develops and the channel morphologically looks the same way as we frequently find in properly tidal channels, and that's why I call them estuarine channels, even though this is not a proper use of the term "estuary".

Such channels are normally stable. They may occur in either sand or gravel, and are common along the Mackenzie, particularly on the east bank tributaries which have relatively small sediment loads and here I have this feature illustrated simply by looking at the mouth of Blackwater River, it's not a good slide and I apologize but it's the only one of the type I have.

A second type which is wide and shallow is lake outlets, and there are quite a few lake outlet reaches in Northwestern Canada, where there are many lakes. Very often lakes spill over bedrock or gravel rims, that are held in by glacial deposits, perhaps, or perhaps by bedrock, and where they spill over these rims the channels are wide and shallow,

and regulate the outflow so if the lake is of some size, extreme floods are damped out downstream from the lake. Usually reasonable stable river sections persist for quite some distance downstream from the lake outlet.

A third type of channel that I would like to draw brief attention to now are delta distributary channels, particularly the distributories of Mackenzie River, and one of the small channels on the Delta is illustrated on the right. These are of the sand bed, silt bank type or possibly silt bank and bed and they are usually stable or shift only slowly. Sometimes in these channels an inner channel is found to be prominent so that you will have outer banks and a fairly wide channel near the surface but then a narrower deep channel inside.

The reasons for this morphology are not clear. One can think of at least two possibilities. One, this inner channel may be the result of scouring processes that occur when flow occurs under ice cover in the winter. Alternatively, near seasonal water surfaces, the banks, particularly if they have got a high ice count in them, may be subject to quite rapid erosion as ice melts from the banks and so the banks may in fact simply be eroded back an unusual distance near the surface of the stream. Bank erosion processes are often quite severe in such circumstances as I will illustrate in a minute.

I would like, just for completeness, to remind you that sometimes fairly major rivers flow on bedrock and here we have a view of Firth River to illustrate rock banks and there will be bed rock at a shallow depth under that gravel fill in the bed of the river at this point as well.

Small channels are very important for very often they are draining head water areas where the effects of changes in the land surface can have quite a serious effect on run off on a local scale, so that very major changes may occur in a short period of time. Types that are quite common include gravel bedded upland channels illustrated on the right. These channels are cobble lined with usually cohesive banks which may themselves be cobble lined as well, or may simply be stabilized by a thick vegetation mat along the bank. These channels are usually not alluvial, that is they are not flowing in their own sediments.

Frequently such upland channels flow on bedrock as well.

River channels in muskeg are characteristically narrow and deep, the banks are well protected by vegetation roots and such channels are stable or they shift laterally only very slowly, the bottom can be of almost any type. These channels frequently flood the surrounding terrain during spring floods as is illustrated in the view on the right.

A special channel type that occurs in permafrost country, is so-called beaded channels. These are very narrow and deep. Very often they are widest below the surface and they are turf banked and they form by thermal erosion of formally frozen ground and commonly, and as Dr. McKay very graphically illustrated this morning, they develop along lines of former ice wedges with the beads

of pondlike enlargements along the length of the channel being initiated perhaps where a large mass of ice melts out possibly where two ice wedges formally intersected and so there is a great bulb of ice.

I might say that these channels are mostly pretty small and when one is working around them it is often a temptation to try and jump over from one side to the other, but if you miss your step you can be in trouble.

THE COMMISSIONER: We will bear that in mind.

A Carry a plank.

A final type of drainage line, really, rather than channel, that I would like to draw your attention, is what I call a tundra seepage. This often occurs without a well-defined channel in the usual sense. Water seeps through peat or grasses often betwen higher so-called inter-sloughs which are sedge or they are often heath and tundra grass, vegetated, and the drainage line is identified mainly by this contrast of vegetation between the heathy tundra surface and the grassy and sedgy seepage areas. Very often slow down slope movement of the surficial material is occurring everywhere in terrain of this sort. Dr. Fyles referred to such, slowly soliflucting slopes this morning.

There is some geographical pattern to the distribution of these channel types which may be of at least preliminary help in further

hydrological work and analysis.

The gravel rivers carrying considerable coarse sediment are found around the Mackenzie Mountains here, rivers such as the Mountain River, the Keele River and Redstone River and the Nahanni River and draining the British mountains of the Yukon north slope. These are areas where there is considerable supply of sediment available and it is this large supply of coarse material that is one of the important features in determining the occurance of these wide, shallow gravel rivers.

By contrast, the east bank tributaries of Mackenzie River draining from lowland areas where precipitation is, consequently runoff is smaller than the mountains, where there is no great sediment supply and many of these rivers being late controlled, so having less propensity to flood to extreme, are generally stable, very often gravel floored, but nevertheless, stable channels.

The sand bed silt bank channels comprise the large lowland rivers, for example, the lower course of Arctic Red River, the Peel River and many smaller rivers, Channels of this type are common flowing through country that is underlaned by the lacustrine clays that Dr. Fyles pointed out this morning.

Muskeg drainage of course is widespread in lowland terrain, everywhere in your study region. Non-channeled flow is common in the north, particularly over frozen ground during the snow

melt period in the sprin g, and I think that it is important to take account of the conditions of non-channeled flow when designing structures or doing any geotechnical work in the North, for change or inadvertant channeling of this non-channel flow may statt to produce severe gullying locally, where previously the flow went merrily on its way and adequately crossed the frozen ground without doing any damage, so that if you inadvertantly concentrate a considerable volume of this water, you may create a channel where none existed before and this may or may not be a nuisance.

As well, lakes are very common in the North. In general, five types can be recognized. In country underlain by permafrost where the degradation of the frost limit -- the limit of permently frozen ground may be occurring, thermokarst lakes occur and Professor McKay discussed these extensively this morning, so I will not say anything more about them, but similarly in areas that were formally occupied by glacial ice and in particular where the ice may become buried in site, rather than melting on the surface, if the ice became buried under its own glacial debris, when the ice subsequently finally did melt, the melting of isolated blocks of ice might cause local subsidence of the surface and then a hole is left called a kettle hole, sometimes fills up with water and becomes a pond or a lake. The hydrology of thermokarst ponds and kettle holes is apt to be similar. In particular many of them may not

have external drainage, that is to say, they may just be self-contained, they receive enough precipitation and run off from local snow melt to maintain themselves against summer evaporation losses and in places such as this, inadvertant activity around these ponds can easily cause a major change in the water balance of these small lakes.

Larger lakes, include those that are held up by dams of glacial material, such as morraines, till and the very biggest lakes of all that are rock rimmed, they are held in by low-lying areas in the bed rock geology and all of the bigger lakes in the Mackenzie region are of one of these two types.

The lakes in river deltas are another type, principally the Mackenzie River Delta in your study region, -- these are formed as a result of river sedimentation processes. These lakes form in all deltas when channels shift or when they extend at the Delta front and an area of open water may be cut off in the course of this activity.

However, these lakes seem to persist for particularly long periods of time on NOrthern deltas, in the normal course of things sedimentation from flood waters which overspill into these lakes periodically, very rapidly fill these lakes up and disappear from the landscape and so the delta surface becomes generally dry ground, but in the North this does not seem to occur. I think that there are two reasons for this.

First, frost aggradation into sediment deposited along the channels often leads to the development of high, quite stable channel banks, so that subsequently flood waters do not get into these lakes nearly as frequently as they might do where channel banks remain low. Consequently they become isolated from frequent receipts of sediment so that they do not fill in very quickly.

Secondly, much of the lake in filling that occurs on delta surfaces appears to be due to the accumulation of organic debris from vegetation that begins to grow around the lake. Reduced growth rates in the far North effectively slow down this process and so once again the lakes persist for a long time.

This feature has not been studied closely to my knowledge , so to demonstrate further to you that the persistence of lakes in the North is not a peculiar feature of just the Mackenzie Delta whose lakes are famous, I have on the right a slide which is a picture of the Dicyoc(?) Delta in Northern Sweden and shows similarly a large amount of open water, although this is properly a sub-arctic delta, this is the lake, this is the river -- this Dicyoc is draining into -- there is a great deal of open water on the surface here, even in the sub-arctic -- although you can see vegetation growing under these lakes.

M.A. Church
In Chief

Then again, if we look at the Peace-Athabasca Delta farther south in Canada, and not too many miles south of here, we see again the same inter-channel depressions that are former lakes and some of them persist, and that we have on Mackenzie Delta and these are filling in largely by plant succession and build-up of organic debris. This appears to occur much more quickly in these areas farther south.

If all this is true one would accept the same -- one would expect, I'm sorry, the same phenomenon on lake persistance to occur on river flood plains where the shift of a river channel might leave some open water, and this view of a meandor bend on Porcupine River confirms that this does in fact occur in the sub-Arctic. The river channel has formerly flowed in each of these areas over here, due to normal erosion and depositional processes, the river has sifted away from these places so it is now over here, but instead of these lakes filling in quite rapidly with over-bank sediment, they persisted for quite a long time.

The data of sediment transport in rivers of Northwestern Canada is restricted to recently instituted suspended sediment transport observations, and some observations of material in solution in a few major rivers. I pointed out briefly the locations, mainly along the Mackenzie main stem where these observations have been instituted. But we really have very little material of a quantitative nature on sediment transport in these rivers, and so we

really do not have a great deal to go on in the way of direct information in making calculations of sediment transport, deposition and erosion rates. River bed scour and fill during floods in northern rivers proceeds in much the same way as it does in rivers anywhere else, and so geomorphological and engineering experience from rivers in other regions will be of use in assessing the scour and deposition conditions due to normal river processes that can be expected in rivers in the north. This is true unless either the river bed is frozen and sometimes may occur, particularly in the winter dry gravel rivers of the Arctic, that the important spring melt-water flood comes down the river when the bed that has been exposed all winger is still frozen, in which case it may resist scour which may otherwise occur. Or when there is ice in the channel, which is capable of modifying flow patterns, or causing direct abrasion on the bed; and in this case the ice may cause peculiar scour features that I will illustrate later on.

In gravel rivers in the Arctic north slope in particular, this view is from below-river, the spring freshet may pass over a gravel bar of this sort whilst the bar is still frozen, and so consequently no damage may occur, where otherwise it may.

River bank stability as opposed to river bed stability is a subject which has some peculiar features for northern rivers that is related to the conditions of the northern rivers.

I have put down here a typology of bank types that can be found, some of them peculiar to the north, some of them not so much. On the left, the erosional types; on the right here, stable bank types; and depositional banks below.

The first type, the thaw niche, which is illustrated on the right, is a peculiarly northern feature. This develops where river waters thaw frozen sediment, usually this is fines with high ice content, though I've seen the same feature develop in frozen gravels as well, and as the thaw occurs at the water line, erosion occurs at the water line. The frozen bank above the water line is left overhanging whilst the niche is eroded back until ultimately the beam strength of this unsupported bank is exceeded, whereupon the whole unsupported bank will slump in the river and this section of the bank has done that quite recently.

Niche development may occur quite rapidly. Erosion rates of several feet a day during spring flood levels are not uncommon, particularly when the water is quite warm, as may be the case if it's flowing down north, in a river that is flowing to the north from regions to the south where conditions may be considerably ameliorated.

In very extreme cases, niches can grow to nearly 10 meters in depth, that would be an extreme case. Usually the bank fails before that.

Vertical banks, high vertical banks are not uncommon in fine sediments along rivers

anywhere, fine sediments -- silts and clays have a cohesion of their own and they're able to stand up in section. In frozen ground they may stand up to considerable height and even develop notable overhangs. As melt proceeds on this vertical face, however, the material is sloughed off and then it is carried away by the river at the base, the bank remains vertical and continues to melt and move back, and erosion proceeds in this way for a long time indeed.

If the river does not move material from the base, then it may pile up on the face and when a sufficient amount of material has piled up the bank may stabilize for a while until perhaps a major flood moves this debris pile and restores a vertical bank and begins to erode the base again.

Amongst protected or stable slopes, lag cobbles, which we've looked at before, that's stones too large for the river to move, and pavements of cobbles that have been scoured into a tight cobblestone pattern by ice movement, ice abrasion over them, are common on northern rivers. As well, vegetation roots often form a rip-rap which effectively stabilizes a bank, although the washing out of fines from under those roots might eventually cause the vegetated material to be torn away and the bank to erode backwards over a long period of time.

THE COMMISSIONER: What do you mean by "fines"?

A By "fine material" I mean silt or clay. I'm sorry.

Depositional bank types include slip-off slopes of meandering river such as this, this is a view of Little Slave River which is regularly meandering, and as this meandering proceeds on the outside banks here where the current is usually quite strong, when the water goes around the corner, erosion occurs on the inside bank;where there is usually slack water, sediment is commonly deposited and builds up what's called a slip-off slope, the river is slipping away from this bank, a depositional bank frequently occurs in such circumstances.

Secondly, channel side bars such as illustrated on the right, constitute another depositional slope type, this type. The difference between these two types, although they're superficially similar, they are both formed by the deposition of fine materials along the river bank, the difference is that since the river is shifting persistently on a meander bend, this slip-off slope deposit (also called a point bar deposit) tends to remain for a long time, whereas channel side bars which may form in quiet water along the side of a river, are apt to be scoured out quite frequently when a major flood comes through and fills the channels to a higher level. These channel side bars, although they're depositional, are not likely to be stable over a long period.

Mechanisms for river bank erosion are shown here, and I've drawn these mechanisms up in such a way that they conform with the mechanisms of general slope instability that have been found in

the Mackenzie River region by other investigators. The major difference between slope instability at river banks and slope instability elsewhere in the terrain is that if the river persistently removes the sediment from the base of the bank slope, then the stability may persist for a long time, and Professor McKay mentioned this fact this morning.

First of all, active layer detachment, simple sloughing of material off the surface where the frozen zone moves back from the surface due to seasonal thaw processes, may occur along vertical or near-vertical banks. We can call this an active layer detachment.

Secondly, retrogressive thaw slides or flows commonly occur, particularly where there is massive ice under the surface which melts out with a lot of water present, a mud slurry is produced which may flow down quite a small slope and so such a slide or flow may remain active for a long, long time, particularly if material is removed from the bottom of the flowing section of the slope.

Thirdly, rotational slumps, the bottom illustration on the right-hand side, may occur frequently along river banks, particularly where tension cracks can occur back from the bank as support for this ground is removed from the front by prior river erosion. This is particularly common in terrain where ice wedges are present; where the ice wedge line provides a point where tension cracks can easily develop, the ground may be weak. In addition, slumps

are of course associated with the failure of thaw niches and in fact this illustration follows the failure of a thaw niche.

Turning from short-term erosional and depositional conditions to those of a long term, I'd like to point out that long-term sedimentation in northern rivers proceeds much as elsewhere so again experience from river studies elsewhere is important in understanding northern rivers in this respect. In the gravel bed-load transporting rivers which develop their deposits by rapid deposition of a lot of material in the channel zone during a flood and then lateral shifting of the channel-way around that sediment pile, it often occurs that the entire channel zone will be periodically re-located to get around sediment deposits. This is known as a bulgeon when the entire channel zone shifts, and is not uncommon on rapidly aggrading gravel rivers. The illustration on the right of the Firth river on its delta sand near the Yukon north c oast shows an old channel zone in the foreground here and behind the present channel zone which is flowing locally here in an entirely different way down the sand _, so at some point in the past the entire channel zone has shifted its course, presumably as the result of local depositional processes in the formal channel way.

As I pointed out, silt-carrying rivers deposit much of their sediment over-bank from suspension, and thereby they build up their flood plain surfaces vertically whilst the river itself may remain within the same channel zone for long periods of time. This is seen in this cut-bank here and this illustration is similar to one that Professor McKay showed

this morning for a different purpose, however, in this case since these trees commenced to grow, a good deal of sediment has been deposited over the bank and now is revealed by erosion of that river bank.

Again, as Dr. McKay mentioned this morning, these fine sediments are often susceptible to the development of ice when permafrost aggrades into them. Along these channels in the north, levies develop near the channel bank. A levy is a ridge along the channel, so that the land farther back from the channel will be lower than the bank itself. This results from the fact that when the river flows out of its channel the water immediately encounters vegetation, slows down and deposits sediment and much of the sediment is deposited very close to the river itself, so the bank builds up quite high.

In the north these sediments may build up and then persist as especially prominent features, possibly protected by becoming frozen. In the view on the right of Mackenzie Delta, virtually all the land is river-levy.

Ice action is important in northern rivers. When ice forms in the autumn it either develops as a continuous cover of skim ice, thin ice which then thickens into sheet ice, and this occurs provided the water flows quietly and the surface is smooth. By flowing quietly I generally mean the flow velocity is less than one foot per second. In such circumstances sheet ice develops on the surface and becomes stable and very often remains that way for

the winter. In rougher flow, generally flows of greater than one foot per second velocity, instead of skim ice and then sheet ice developing, what may happen -- and this diagram shows skim sheet ice and a continuous ice cover developing on this side -- it may get broken up before it becomes stable, in rougher flow platelets and spicuals of ice form in the flowing water, rather than a continuous cover forming individual plates and spicuals of ice develop at the surface and also growing on the channel bed. The ice that develops in flow, which is known as frazil ice, continues to run down the river with the flow. If it develops quite extensively, then individual plates and spicuals of ice will come together and form frazil slush, and these will continue to run down-river with the flow until they meet some impediment. This impediment might be a section of the river where a stabilized cover has developed where the flow is quieter there. When this occurs, the frazil piles up against this impediment and the frazil slush pile progresses upstream as more and more ice piles in. Now this may freeze and stabilize itself.

In some occasions, however, the flow is strong enough the frazil ice may be drawn under the unstabilized cover and then it may stick under the ice cover somewhere farther downstream, and develop into what's known as a hanging ice dam. The significance of this feature is that under the hanging ice dam the area available for water flow is restricted. In order to overcome this, water levels may rise up-

stream and force water under this dam at higher velocities than previously, and consequently local scour may develop on the bed of the river under the location of these frazil-ice dams which I show developing here.

This process of development of jamming of frazil ice and progression and hanging ice dam development may form, water pressures against the dam may become so great that ultimately the whole thing breaks up, the ice continues to run down the river and then the sequence may repeat again. Or alternately, a stabilized cover may form and the situation may stabilize.

More important than these winter ice runs and jams are events that may occur in the spring. In the spring stabilized cover on the rivers is usually first broken up by rising water levels as snow melt water finds its way into the river channels. This produces an upward pressure on the ice cover, and the ice cover often breaks off from the shores at shore base, some ice remains attached to the shore but the ice breaks and transverse breaks also occur across the river channel.

After this, if the water rises quickly and brings considerable pressure to bear massive ice movement may begin once the ice has been broken loose from the banks. The ice may move down the river breaking up into pans and continue to move until a constriction is reached, usually a narrowing of the channel or perhaps a sharp bend in the channel, where a major jam may develop. The ice wreckage may

start to pile up here because it can't all get through the constricted section of channel and then a major jam may occur. In general, the rapid rise of high water levels in the spring will produce relatively rapid ice clearance, but with the possibility for very large jams to occur, since the ice is moving down the river quickly. If there's a slow rise in water levels, and a moderate water level reached, the ice may persist much longer on the river but there will be many small jams and the chances of a really major jam developing somewhere are smaller.

Now the speed with which water levels rise, of course, will depend on weather conditions, the rapidity of snow melt and so on. So whether or not major jams develop is a function of the weather sequence in any one year.

This graph which plots ice thickness on this axis and the number of days necessary to clear the ice on this axis and shows by different colored symbols, different types of ice cover, illustrates that in Northern Canada it takes from a few days to greater than a month for breakup to completely occur. On the rivers, which are the red symbols, with few exceptions breakup occurs within about three weeks; and if currents, river currents are very important, the breakup can occur in only a few days. When breakup occurs in circumstances like this, then the possibility exists for massive jamming to occur. When breakup takes considerably longer to be completed, ice is not moving as quickly or as

frequently, and major jams are not so apt to occur. None of these statements can be made absolute for peculiar conditions in any one year might produce a really major jam, as a result of chance circumstances.

The time of year when breakup occurs is, in the study region, generally late May. It's interesting that along the Mackenzie River from Fort Simpson to near Fort Good Hope, breakup is practically synchronous. This is the result of the influence of the major snow melt flood coming out of Liard River both upstream from Fort Simpson and downstream from Good Hope, it's usual for breakup on Mackenzie River to be later than the time when breakup occurs on this section of the river. But generally between about May 15th and May 30th, breakup occurs almost everywhere in the study region of interest, out in the Mackenzie Delta and Yukon coast; the first week in June is a useful more/mean date to think about.

When ice runs in wide shallow gravel rivers, those that are often empty during the winter -- and ice doesn't always run in these rivers but it may remain anchored to the bed throughout the spring snow melt flood -- but when it does run it may abraid the bed directly as it moves down the wide and shallow channels, or the ice may run up on the river bars, such as the bar I illustrated a while ago. If the material on the bars is unfrozen, it may be abraided as is indicated by the very irregular pattern of material on this channel bar in Babbage River on the Yukon north slope, and where individual blocks of ice

come to rest, patterns of scour around the ice blocks and sediment deposition in the lea of them, may considerably disturb the bar surface. In sum, the absolute depths of scour are not usually very deep, but an irregular pattern may occur. It may occur in a different way from year to year and over a period of years it may lead to the destruction of a river bar deposit that may appear in the short term to be reasonably stable.

On rivers that contain a surface ice cover and flow under the ice cover through the winter, ice wreckage which moves down stream on the rising water levels in the spring may pile up to produce major dams as illustrated -- major jams, I am sorry -- as illustrated by the mouth of Willow Lake River here and by the Mackenzie River near Norman Wells. BOth of these photos were taken on May 14, 1973.

In situations such as those, the ice may scour the bed directly where it grounds under the bed and it may push debris to high levels on the banks as is illustrated in these two pictures, both of them along the Mackenzie River. Major ice jam sites are at points where the river narrows or turns sharply and so jams tend to recur at the same sites from year to year. For example, the major locations of recurrent ice jamming on the Mackenzie River are illustrated on this slide, so we can identify those points where ice jams are most likely to recur and threaten structures on the river bank.

Where flows must pass under a major jam or under a hanging ice dam in winter, the restricted passage may produce scour on the bed. The four crossections and these are sonar tracks, illustrated on the right are from the Mackenzie River just donwstream from the confluence with Arctic Red River, just down here and on two of these the exaggerated depth of the inner channel may indicate the effect of scouring under ice wreckage. I cannot be sure of this for the observations being directly

made during or following an ice run. The vertical scale here is that each major division is seven feet, so all of these sections are approximately 30 feet deep, with the exception of the top one, which is only some 20 feet deep. -- I am sorry -- all of them are twenty feet with the exception of this one which is over 30 -- the reverse.

I would like to look at icings briefly. Icings can be classified into several types. Dr. Fyles introduced icings this morning as a feature found along Northern rivers where water is forced to the surface during the winter for some reason and there freezes to form large accumulations of ice, such as is illustrated on the delta fan of the Firth River here and this is the same icing that Dr. Fyles illustrated this morning.

River icings occur on top of river ice cover when water is forced to the surface, either by the hydrostatic pressure of water flowing through gravels from upstream encountering frost closure downstream, so that if there is permanently frozen ground under the river bed, and then a seasonally developing frost layer moves toward that permafrost table from the surface, closure may occur and water flowing in the unfrozen ground upstream may then be forced to the surface.

Similarly, if closure occurs both upstream and downstream, the water left in the unfrozen gravels between these two points, as freezing continues, will come under increasing pressure,

for ice being less dense than water takes up more volume and so the volume available to the remaining water will be steadily more restricted. In either case pressure develops and finally the frozen cover may be ruptured by this pressure and water moves to the surface and freezes.

Icings at springs of course may occur at the surface at or downstream from the site of resurgence of the spring and in some places in the mountains of Northwestern Canada, thermal springs continue to flow through the winter and icings may develop near them, and finally small icings may occur near the base of slopes where non-channel seepage comes to the surface, but these are usually minor.

In this view, also of the Firth Delta icing, spring runoffs have flowed over the icing and has deposited sediment on it. This illustrates the salutary effect of icing, that it may protect a section of the river bed from possible scour during floods. To illustrate that these features are quite common, particularly on the gravel rivers of the northslope, here is an icing on Trail River, some miles to the east of Firth River.

Icings have two major effects on river stability. First, although they usually form on the surface, it is possible in a closed system icing, that is where there has been frost closure both upstream and downstream for the water to be trapped and frozen below the river bed and for the frozen

river bed, above the unfrozen gravel and water, to be sufficiently strong that rupture does not occur at a specific site. When this occurs the whole river bed may be heaved upward and this is illustrated in the slide on the right. In the following summer of course, water flows down the channel, past this heaved site, begins to erode it, largely thermal erosion occurs, and as the ice melts the sections of heaved channel bed fall off into the river and are moved some distance down stream.

The particular importance of this feature which, so far as I know, has not been stressed anywhere in geotechnical literature previously, is that a channel bed which is stable, under normal river processes, a channel bed consisting of lag cobbles, for example, which we described awhile ago may be disturbed, completely derranged, due to a process such as this and so the bed may become unstable in the vicinity of icings of this sort that actually grow under the river bed.

The second effect of icings on river stability is that some times they grow in the winter and fill up the entire channel and these are two views of Canyon Creek, the small creek near Norman Wells, one in the autumn and the other view in the following spring. In the winter an icing is developed which substantially fills the channel, it does not melt out before the spring flood occurs and so the spring flood pours over the icing and may thereby get right out of the river channel. Once outside

the river channel, it may go almost anywhere down valley and in particular this may be a cause of evulsion of the river, movement outside its channel and rerouting of the river channel and in particular this may threaten structures that are built at or near the banks of the rivers downstream, if they are exposed to this sort of action.

As a final aspect of Northern Rivers, it is interesting to ask about the long term behaviour of the river. At the end of the last galcial period which Dr. Fyles introduced this morning, the abundance of sediment that is available to the rivers around the margins of retreating ice sheets, led to large scale sediment transport and aggradation of river beds, producing valley fills of sediment as seen on this view of Bow River, on the left is gravel sill in the river valley is produced largely early, in the early period after the last glaciation, some seven to ten thousand years ago and on the right, away from valleys, large sheets of outwashed material were deposited on the coastal plains here on the Yukon north slope.

Similarly, features usch as these alluvial fans of sediment here in front of the Richardson Mountains near Aklavik were largely built up during this period early after the end of the last glacial episode. Since that time increased vegetation cover, the exhaustion of unusual exposed, unconsolidated sedimentary -- sediment supplies, and reduced run off with the disappearance of the

glaciers have greatly reduced the rate of sediment movement and this is ended general aggradation in the rivers of this region.

The rivers have responded to this change in the conditions of sediment supply and runoff by becoming stable or by degrading slightly. This view of Malcolm River on its fan, on the Yukon north slope, shows several terraces along the edge of the channel, here are several terrace levels. They are low terraces, but terraces they are and this indicates that the channel has degraded slightly into its own sediment deposits. Usually in gravel channels of this sort after slight degradation, the channel bed becomes floored by lag cobbles moved during the early period of aggradation but not movable during the subsequent period of reduced river flows and then the channel stabilizes.

Further evidences of this change in the long term sedimentiary environment are evident on the coastal deltas on the Yukon north slope, these deltas were actively built out into the sea during the early post glacial period, but now sediment delivery to these deltas is not sufficient to prevent erosion and trimming back of the deltas by the sea and so we see land areas on the distal portions of these deltas being reclaimed by the sea through processes of coastal erosion.

In summary, many of the rivers today are stable and over long periods of time, probably to be judged in centuries or perhaps even millenia

-- they may be degrading significantly. Only locally where there are unusual sediment supply conditions upstream is considerable aggradation to be found. In small watersheds where changes in surface vegetation particularly fire, or perhaps the result of large scale geotechnical activities, are found, such a sediment supply may be provided by the surface sediment becoming bare and exposed to the erosive effects of running water.

Larger rivers, it's not likely that such an unusual sediment supply will affect the stability of the entire length of the channel at any one time. In the Mackenzie and the British Mountains there is still considerable sediment being delivered to some rivers as a result of erosive processes in the high barren headwaters of these water sheds,and these are the places where most sediment movements are occurring under natural circumstances today.

In closing, I should like to remind everyone once again that much of what I've said amounts to impressions, and reconnaissance observations. As in many other things in the north, we have relatively few records of data that are long enough to be significant in interpreting what goes on. I think this makes it particularly important to deduce properly what we can say about the hydrology and river processes from what we can see of the appearance of the river channels, and other features associated with water in the north. That is why I've emphasized the morthology of the rivers and their sediment deposits in this discussion, and I hope my discussion has clarified some of these points.

THE COMMISSIONER: Thank you very much, Mr. Church. You've been most helpful.

(WITNESS ASIDE)

MR. SCOTT: Mr. Commissioner, I should point out to you and the other counsel present that we are making efforts to obtain copies of all the slides or alternatively photographs from the slides

that have been used today and will be used on other days, and in due course I would propose to file them as exhibits so that the evidence you've heard today will be meaningful with reference to them, and when we are able to do that I will notify you and the other parties.

I suggest, sir, if there is nothing further to be done today that we should adjourn until nine o'clock tomorrow morning.

THE COMMISSIONER: We'll adjourn then until nine o'clock sharp tomorrow morning.

(PROCEEDINGS ADJOURNED TO MARCH 5, 1975)